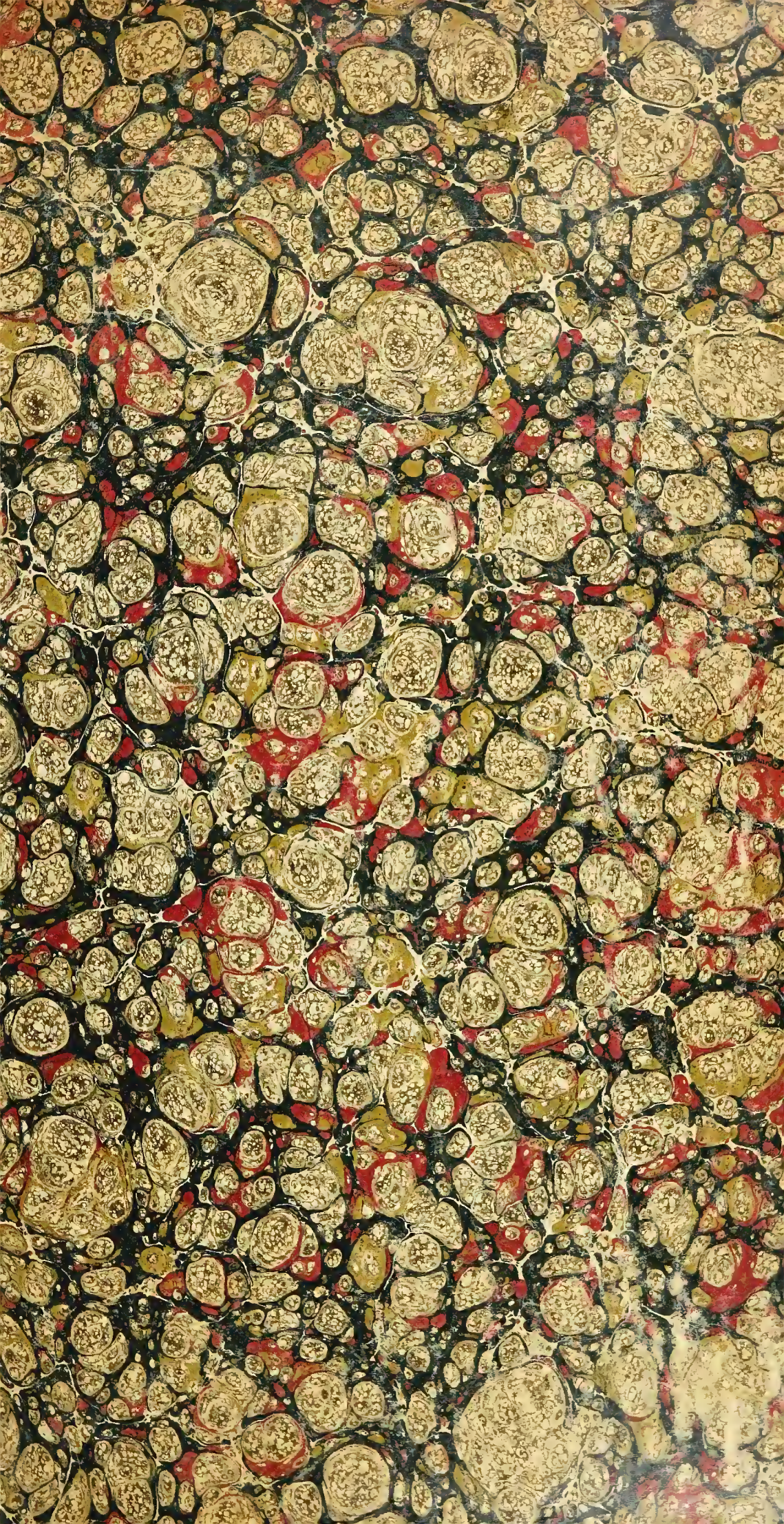

London County Council.

REPORT

BY

MR. W. J. DIBDIN, F.I.C., F.C.S.,

CHEMIST AND SUPERINTENDING GAS EXAMINER TO THE BOARD,

ON THE

STANDARDS OF LIGHT.

Ordered to be printed by the Special Purposes and Sanitary Committee of the Metropolitan Board of Works, 24th February, 1885.

Ordered to be reprinted by the Sanitary and Special Purposes Committee of the Council, 3rd May, 1889.

(No. 1,153.)

JUDD AND CO., LIMITED, PRINTERS, DOCTORS' COMMONS, E.C.

London County Council.

CHEMICAL AND GAS DEPARTMENT,
SPRING-GARDENS.
February 24th, 1885.

To the
Special Purposes and Sanitary Committee.

In accordance with the instructions of your Committee of the 29th July, 1884, directing me to report exhaustively upon the important subject of the Standards of Light, I have the honour to submit the following results of a necessarily lengthy series of experiments thereon.

The question of photometric standards has engaged the attention of numerous experimenters since 1760, when Bouguer proposed candles as the unit of comparison. From that time candles of various kinds have been suggested, viz., wax, tallow, paraffin, stearine, and sperm. The candle at present in use in England was described in the Metropolis Gas Act of 1860 as "sperm candles of six to the pound, each burning 120 grains per hour."

The uncertainty attending the use of candles was noticed at an early date; and various substitutes have been proposed from time to time. Amongst these are the four-wick lamp of Potter; the Carcel lamp; Keates' sperm oil lamp; Bunsen and Roscoe's carbonic oxide flame; Crookes' alcohol and benzol flame; Von Wartha's ether flame; Vernon Harcourt's Pentane or air-gas flame; Fiddes' aperture; Wolf's screened moderator lamp; Hofner-Alteneck's amyl-acetate flame; Methven's screened Argand flame; Edgerton's screened petroleum reading lamp; Rudorff's screened Argand flame; Draper's, Zollner's, Schwendler's and Violle's incandescent platinum and silver units, and various electric incandescent lamps. For the purpose of ascertaining the quality of ordinary coal gas, various devices have been employed, such as the length of a gas flame at known pressures. In 1836 Alcock proposed such an arrangement, the gas being burnt in the form of a jet; hence the term "jet" photometer. In 1849 Fyfe conducted a series of tests of this nature, which he termed the "durability" test. In 1860 Lowe devised his well-known jet photometer, which was afterwards improved by Kirkham and Sugg, and, in that form, is in constant use at all gasworks as a ready and valuable index of the quality of the gas during the various processes of its manufacture. In 1867 a patent was granted to Warburton for an invention by Friedleben for a similar but more complicated arrangement. Bablon's "photophlogometer" was devised in 1875, and Sugg's 10 candle test in 1882. Various other experimenters have made suggestions and devised apparatus; but their work seems to have ended with the publication of the fact.

The only devices amongst the large number proposed which have at all come to the front are the sperm candles, which are at present the only legal standard of light in this country; the "Carcel" lamp, the standard in use in France; Harcourt's one candle air-gas flame; Methven's two candle screened Argand flame; Keates' sixteen candle sperm oil lamp; and Sugg's "ten candle test." Great advantage has been claimed by the French for the incandescent platinum unit, but, as I shall presently show, this is not altogether free from serious objection.

The jet photometers and the illuminating power meter are admirable devices for

readily ascertaining the approximate value of illuminating gas, but they cannot be admitted as standards of light, nor, in fact, is that property claimed for them.

I have therefore paid attention to the following proposed standards, which promise, by the general attention they have excited, to yield more satisfactory results than the more numerous but less trustworthy arrangements. These are, in historical order, the French "Carcel" colza oil lamp, 1800, equal to about 9½ candles; Keates' sperm oil lamp, 1869, equal to 16 candles; Harcourt's Pentane or air-gas flame, 1877, equal to 1 candle; Methven's screened Argand flame, 1878, equal to 2 candles; and Sugg's 10 candle test, 1882, equal to 10 candles.

Before dealing with these *seriatim*, I would desire to draw the attention of your Committee to the decision of the Congress held in Paris in 1881, when the carcel lamp was recommended, and the French Government requested to "place itself in "relation with foreign Governments to effect the formation of an International Com- "mission, to be charged with the determination of a definite luminous standard, and "the arrangements to be observed in the execution of experiments of comparison."

The same Congress rejected the fused platinum and silver standards of MM. Violle and Cornu, on account of the difficulty attending their application, and the colour of the light emitted from them. These proposals were, indeed, merely resuscitations of those made in 1844 by Mr. Draper, and in 1859 by M. Zollner, and more recently by M. Schwendler. They have been very carefully examined by M. Crova, who unhesitatingly condemned them.

On the 25th August, 1881, the Committee appointed by the Board of Trade to inquire into "the relative merits of the standard at present in use for estimating the "illuminating power of coal gas, and of the standards which have been proposed by "Mr. A. G. Vernon Harcourt, Mr. T. W. Keates, and Mr. J. Methven," presented a report upon these. The conclusions arrived at by this Committee were, shortly —1st. That Candles are not of constant composition; that the melting point of the sperm varied; that the number and size of the threads in the wick, its treatment and closeness of plaiting of the strands, &., affect the light of the candle, and that manufacturers differ in regard to them; that they found a difference of 15 per cent. in the average illuminating power of legal candles, and a maximum variation between two pairs of candles of 22·7 per cent. 2nd. That Mr. Keates' lamp "falls "short of the requirements of a standard of light." 3rd. That Mr. Methven's system has the advantage of extreme simplicity; that while the light obtained from it with coal gas ranging in quality from a little under 16 candles to a little over 18 candles is practically uniform, the light is more than 10 per cent. greater when the burner is supplied with coal gas of 19·5 candle power. Since in practice the coal gas to be tested may vary in quality over a range as great as that between 14 and 20 candles, the indications of the Methven lamp, supplied by the same coal gas as that being tested, are untrustworthy, in the absence of any other check on the illuminating power of the gas; and that they considered that Mr. Methven's lamp in its (then) present form has not that exactness over such a range as is necessary for a standard of light; but where there is no liability to a greater alteration in the quality of the coal gas than about two candles, the ease and rapidity of Mr. Methven's system may render it extremely useful for determining the illuminating power of gas. 4th. Compared with the sperm candle, Mr. Harcourt's air-gas flame is exact and trustworthy as a standard of light.

The conclusions arrived at by the Committee were strongly combated both by the

late Mr. Keates and Mr. Methven. The fact that Mr. Keates' lamp is a 16-candle lamp, and intended for use only when the light afforded by it varies within the limits between 16 and 17 candles, is a sufficient justification for the late inventor's distrust of the conclusions of the Committee, when it is pointed out that in none of the few tests made by the Committee did the lamp burn within these limits, the actual illuminating power, calculated from the consumption of oil, being—

1st test	11·50 candles	4th test	17·41 candles.
2nd ,,	18·02 ,,	5th ,,	15·13 ,,
3rd ,,	17·20 ,,	6th ,,	15·34 ,,

In 1883 the Council of the Gas Institute, feeling great dissatisfaction at the results arrived at by the Board of Trade Committee, appointed a "Standards of "Light" Committee, to inquire into and report upon the subject, but limited the inquiry to an investigation of the sperm candles, Mr. Harcourt's air-gas and lamp Mr. Methven's screen, M. Giroud's "Verificateur," and the "Relative" standard of the same gentleman. This Committee engaged the services of Messrs. Heisch and Hartley to conduct an elaborate series of experiments, with the result that these gentlemen reversed the verdict of the Board of Trade Committee. The following extracts from their report will clearly indicate their opinion:—

"It will thus be realised that the range in the qualities of the gases with which "the Methven plain gas standard can be safely used, is much wider than has been "generally supposed; as in our experiments the extremes are 13·65 and 22·4—a "range of 8·75 candles . . . The Methven standards are simple in construction, "not liable to get out of order, and extremely easy to use. They do best, like "candles, in an open photometer; but can be readily used in a closed one, if due "care is taken to freely ventilate the photometer and avoid violent air currents— "conditions which are exceedingly difficult to fulfil with closed photometers. . . ". . . The only conclusion which can be drawn from such a mass "of evidence is that the Methven units are not only perfectly reliable "instruments for ordinary gas testings, but are suitable for use in photometric "investigations of a much more refined character. . . . . "We feel compelled also to say, although with reluctance, that we cannot regard "Mr. Harcourt's standards as convenient, or at all suited for use in general photo- "metry. They demand too much attention from the operator; with an ordinary "photometer his attention is divided between the air-gas flame and the observations "of the disc, for it matters not how carefully either the prepared gas flame or the "lamp flame be adjusted (even when the former is controlled by a governor), the "flame length will change; and a little change is sufficient to produce a serious "error. Besides this the flames are very sluggish and unstable. The least current "of air affects them, and causes them to swerve from the perpendicular, and where "this takes place observations at the photometer are useless. Further, they require "a freedom from the vibration of the room and of the apparatus, which is rarely "obtainable. During our operations at Horseferry-road the hurried footsteps of any "person near the testing-room, the slamming of the outer door, the fall of any "moderately heavy body in the yard—nay, the very operations in constructing the "new gas-holders at about 30 or 40 yards distance, were felt, and caused the lamp "flame to start with a series of jerks, and then to increase in its length. This "occurred in a building which is unusually firm and solid. We certainly expected "that the experiments would have been favourable to Mr. Harcourt's proposed "standards, and regret that the contrary is the case. Of M. Giroud's instruments

"we have said enough, and can only repeat that, meritorious as they are, they are "not in our opinion exact enough to be adopted as absolute units."

With reference to candles, the same gentlemen in their report state that, "In "our experiments the differences in the indicated illuminating power by candles "range from 1·3 per cent. to 16 per cent.; the average difference being 7·05 per "cent. The maximum for 16-candle gas equals a difference of 2·56 candles; the "average a difference of 1·128 candles. Such extremes as we realised are due to our "resolve to study the behaviour of candles as sold for photometric purposes, which "led us to use some, although they did not burn satisfactorily; specimens which in "ordinary operations we should have rejected. . . . No such wide differences "as we found are shown in Mr. Gandon's or in Mr. King's results."

The reporters then make a very remarkable statement. They say, "We may here "mention what we are convinced to be a fact, namely, that sperm candles generally "now develop more light per grain of sperm burned than they did several years "ago."

Your Committee will thus see that the conflict of opinion is upon the question of the pentane air-gas *versus* Methven's screen. Both of the Committees agree in condemning candles, whilst the Board of Trade Committee put on one side the Keates' lamp, after only six tests, which, as I have shown, were so extraordinary in their character as to warrant the assertion that they certainly did not try Keates' lamp. Unfortunately, the failing health of the inventor precluded him from fighting the cause of his lamp, as he certainly would otherwise have done, and I have therefore felt justified in submitting it to a full and searching examination. The results obtained, as will be seen later on, fully justify the claims made on its behalf. I have also made a careful series of experiments with Mr. Sugg's 10-candle test, which has been devised since the date of the Report of the Board of Trade Committee. In order to obviate, as far as possible, those errors which unavoidably creep in during an investigation of this character, I have availed myself, in certain of the experiments, of the services of the staff of competent photometrists attached to my department in the capacity of gas examiners, whose daily experience in photometry is a guarantee at once of their accuracy of observation and careful working. To these gentlemen, viz., Messrs. Broughton, Damon, Halford, Hehner, Lloyd, Marks, Mills, Williams, and Wood, and to Mr. W. J. Livingston, I desire to offer my sincere thanks for their valuable help, and more especially so to Mr. Robert Grimwood, whose experience in practical photometry has been of great advantage in such an investigation as the present.

Dealing with candles and the various proposed substitutes in the order of their introduction, I propose to consider—1st, candles; 2nd, the Carcel lamp; 3rd, Keates' lamp; 4th, Harcourt's Pentane; 5th, Methven's screen; and 6th, Sugg's 10-candle test. Before describing the results of my tests with these, it will be well to briefly state the system I adopted for obtaining a comparison flame for the purpose of testing the standard under examination, and the photometer, &c., used.

COMPARISON FLAME, OR STANDARD OF REFERENCE.

The difficulty of obtaining a gas of constant illuminating power during a prolonged period has been admitted by all photometrists. The Board of Trade Committee had the great advantage of a coal gas specially stored and kept for their use in a large gas-holder at the South Metropolitan Gas Company's Works at Peckham.

The Gas Institute Committee had a sample of stored gas reserved for their use by the Gas Light and Coke Company, at the Horseferry-road Station, but they met with the disadvantage of a continual depreciation of the illuminating power of this stored gas, so much so that it fell during the course of their experiments from 16 candles to 10 candles.

The Gas Light and Coke Company courteously offered to place a similar holder full of gas at my disposal for the purpose of the present inquiry, but as I should, in that case, have been obliged to conduct my experiments away from my laboratory, which would have entailed great inconvenience, I was, with regret, obliged to decline their offer. Mr. Trewby, the Engineer of the Company, then kindly offered to lend me an experimental 100-ft. holder with which to store gas sufficient for two days, Mr. Harrison, the Distributing Engineer, remarking that the results during those two days would be comparative. This offer I gladly accepted, and the holder was placed, under the direction of Mr. Kitt, the Engineer of the Pimlico Gas Works, in the yard just outside the testing-room, and protected from exposure to the weather by means of a suitable covering. The gas from the large 48-inch main running past the Board's offices from Beckton to Westminster was laid on to this holder, and used as required, the gas being courteously supplied by the Company free of charge.

At first I found great difficulty in obtaining constant results. The rapid depreciation in the quality of the gas, by reason of its storage over *clean* water, was so great that I was in despair of obtaining any useful indications. I next tried the device of burning ordinary gas from the main, in a standard burner, sufficient to yield a flame 3 inches in height, and using only that portion of light emitted from the centre, by cutting off the rays from the top and bottom of the flame by means of screens. This arrangement answered fairly well. However, eventually I availed myself of the fact that the gas, when stored in the 100-ft. holder, deteriorated to a certain point and then remained stationary. As the holder was enclosed in a weatherproof structure I was enabled to obtain that which Mr. Harris proposed, viz., a gas of constant quality, sufficient for two days' work. This was, however, not constant for two days in all cases, as differences of temperature made great differences in the quality of the stored gas. The results obtained are calculated to percentages, by which means the work done at various times is rendered comparable.

APPARATUS.

The photometer mainly used was an open bar 75 inches long. The standard to be tested was placed in a well and evenly ventilated box, at one end, for the purpose of screening the light from the observer, and also to protect the flame from draught. The apparatus as arranged had been inspected and certified by the Gas Referees under the Gas Light and Coke Company's Act. In some of the comparison tests two other forms of photometers were used, viz.: the "Portable" and the "Radial," which latter instrument is an entirely new form, constructed to my designs by Messrs. Sugg and Co., for estimating the light emitted from various burners, &c., in all directions.

The Keates' lamps employed were four in number, two of these having been in use by the inventor, the others having been constructed recently.

The apparatus for making and storing the pentane air-gas of Mr. Harcourt, consisted of two experimental holders, one of five cubic feet, and the second of 11 cubic

feet capacity. Both of these holders had been examined and stamped by the Standards Department of the Board of Trade. The meter governor, &c., for regulating the supply of pentane gas, was fitted up under the personal supervision of Mr. Harcourt.

The Methven screens tried were four in number. The first was supplied to the late Mr. Keates soon after its invention; the second is a double-slotted lamp, arranged for burning either plain or carburetted gas; the third is a copy recently supplied to Professor Wm. Foster, who kindly placed it at my disposal for the purpose of comparison; the fourth is one fitted to the "Radial" photometer.

Two Carcel lamps were tried; the first was kindly lent by Messrs. Sugg and Co., and the second by Mr. F. W. Hartley, who sent with it the balance, oil, and wicks which he had recently obtained from Paris.

CANDLES.

The numerous experiments of the two Committees already referred to would seem to have rendered unnecessary any further experiments with candles with the view of showing their unreliability. This is indeed the case, but as not a few photometrists have expressed the opinion that candles have not been always fairly treated, I have thought it best to make a few additional tests in such a manner as to obviate all considerations of bias on the part of the observer, and to illustrate the actual results which are constantly obtained by Gas Examiners in daily practice.

With this view I instituted two series of experiments, which were carried out on the 23rd, 25th, 29th and 30th October last. The object was to show,—1st—The difference in candles obtained from those makers who supply the bulk of candles used in photometry; and 2ndly—The variations obtainable when candles, burning within the prescribed limits, are used precisely in the manner and by the same observers as they are at the Metropolitan Gas Testing Stations.

The first series, Table No. II., demonstrates in a remarkable manner how the illuminating power of a given flame may be made to appear extremely variable. On the first day the average of tests with candles made by Firm A showed the illuminating power of a gas flame to be equal to 15·76 candles; while candles manufactured by Firm B gave a value of 14·94 candles—a difference of 0·82 candles. On the second day a still wider divergence was found; candles A gave a value o 14·81 to a constant gas flame; while candles B gave a value of only 12·86, or *two* candles less. It may be objected by the advocates of candles that the number of tests made were insufficient, but, as I have stated above, these results have been so often confirmed, that no useful result would accrue from their repetition.

The second series, Table No. III., was designed to show the difference in the results when the average of three or more tests are taken. On the first day of this series the tests were made solely with the candles of one maker and from one packet. The greatest difference obtained in the average of three tests, each consisting of three complete observations, was 1·3 candles; the greatest difference between any two single observations was 2·0 candles. On the second day the observations were repeated, when the greatest difference in the average of three tests as before, was only 0·31 candle; but the greatest difference between any two single observations was 1·33 candles, and this was with one candle. This

candle alone gave such remarkable variations, not only in the hands of differ e observers, but also in the hands of the same observer, that it was sufficient in itself to throw great discredit upon the system. The following are the recorded tests, viz. :

1st observer	1st test	16·65		3rd observer	1st test	17·00	
,, ,,	2nd ,,	15·67		,, ,,	2nd ,,	16·70	
2nd ,,	1st ,,	15·87					

It is, however, only fair to the candles to call attention to the very different results obtained when they are used in an open room, without protection of screens, boxes, &c., which, while intended to enhance the regular burning of the candles, evidently tend occasionally to seriously vitiate them. I have tabulated (Table IV.) some of the tests made with the portable photometer, in which candles are used without any attempt to foster them, except the prevention of decided draught. From these representative results it is evident that, although occasionally the tests are erratic, candles are indeed capable of more uniform working than the above results would indicate.

In consideration of the foregoing results and the general experience with candles I respectfully submit to your Committee that the condemnation which they have met with is not undeserved; and that, as speedily as possible, they should be rejected as the standard of light.

Your Committee will now readily understand that Messrs. Heisch and Hartley found that "candles develop more light than they did a few years back," but there seems to be no reason why they should not have found the contrary. I propose to consider this important point after the discussion of the results obtained with the various proposed standards.

TABLE I.—CANDLES.

SERIES No. 1.—Difference between candles obtained from two manufacturers—In order of tests.

Date. 1884.	Candles.		Weight of Candle used. Grains.	Length from shoulder. Inches.	Diameter at		Wick. Strands and Treads.	Consumption of Sperm. Grains per hour.	Heights of flames. Inches.	Value ascribed to comparsion flame.	Percentage variation from Mean.
	Maker	No.			Shoulder. Inches.	Bottom Inches.					
Oct. 23	A	1	1169	9·0	0·75	0·86	3 of 17 each	122·1	..	15·44	— 0·7
,, ,,	,,	,,	,,	,,	,,	,,	,,	120·6	1·75 & 1·8	15·25	— 1·9
,, ,,	,,	2	1169	9·0	0·79	0·86	,,	121·8	2·0 & 1·75	16·15	+ 3·8
,, ,,	,,	,,	,,	,,	,,	,,	,,	119·7	2·0 & 7·6	16·10	+ ·5
,, ,,	B	3	1142	8·75	0.79	0·86	3 of 23 each	117·9	1·75 & 1·85	15·08	— 2·9
,, ,,	,,	,,	,,	,,	,,	,,	,,	114·0	1·75 & 1·80	14·80	— 4·8
,, ,,	A	2	1169	9·0	0·79	0·86	3 of 17 each	126·3	1·9 & 1·9	15·64	+ 0·5
,, ,,	,,	,,	,,	,,	,,	,,	,,	120·3	1·8 & 1·9	15·97	+ 2·7
									Mean	15·55	
Oct. 25	B	4	1155·5	8·75	0·79	0·86	3 of 23 each	116·1	1·8 & 1·76	12·92	— 5·8
,, ,,	,,	,,	,,	,,	,,	,,	,,	114·3	1·6 & 1·69	13·31	— 3·0
,, ,,	A	5	1167·3	9·0	0·79	0·88	3 of 17 each	121·2	1·85 & 1·95	14·76	+ 8·0
,, ,,	,,	,,	,,	,,	,,	,,	,,	117·9	1·65 & 1·95	15·74	+14·9
,, ,,	B	6	1148·0	8·75	0·79	0·88	3 of 23 each	117·0	1·73 & 1·73	12·56	— 8·3
,, ,,	A	5	1167·3	9·0	,,	,,	3 of 17 each	125·1	1·70 & 1·75	13·94	+ 1·8
,, ,,	B	6	1148·0	8·75	,,	,,	3 of 23 each	117·9	1·65 & 1·80	12·65	— 7·7
									..	13·70	
									Mean		

Table II.—CANDLES.

Series 1.—Difference between candles of two makers, arranged in order of candles.

Date.	Candles. Maker.	Candles. No.	Consumption of Sperm Grains per hour.	Value given to Standard Gas Flame.		Percentage variation from mean.
October 23rd	A	1	122·1	15·44		−0·7
,, ,,	,,	,,	120·6	15·25		−1·9
,, ,,	,,	2	121·8	16·15	=15·76	+3·8
,, ,,	,,	,,	119·7	16·10		+3·5
,, ,,	,,	,,	126·3	15·64		+0.5
,, ,,	,,	,,	120·3	15·97		+2·7
,, ,,	B	3	117·9	15·08	=14·94	−2·9
,, ,,	,,	,,	114·0	14·80		−4·8
				Mean 15·55		
October 25th	A	5	121·2	14·76		+ 8·0
,, ,,	,,	,,	117·9	15·74	=14·81	+14·9
,, ,,	,,	,,	125·1	13·94		+ 1·8
,, ,,	B	4	116·1	12·92		− 5·8
,, ,,	,,	,,	114·3	13·31	=12·86	− 3·0
,, ,,	,,	6	117·0	12·56		− 8·3
,, ,,	,,	,,	117·9	12·65		− 7·7
				Mean 13·70		

Table III.—CANDLES.

Series No. 2.—To ascertain possible variation in results, when the operations are conducted in accordance with instructions of the Gas Referees.

Date. 1884.	Candles used. Maker.	Candles used. No.	Consumption of Sperm. Grains per hour.	Value ascribed to comparison flame.		Percentage variation from Mean.	Observer.
October 29 ..	A	7	123·6	16·50		−0·5	F
,, ,, ..	,,	,,	115·8	16·40	=16·43	−1·2	,,
,, ,, ..	,,	,,	120·0	16·40		−1·2	,,
,, ,, ..	,,	8	118·5	17·75		+7·0	A
,, ,, ..	,,	,,	120·0	17·15	=17·35	+3·4	,,
,, ,, ..	,,	,,	119·1	16·86		+1·7	,,
,, ,, ..	,,	9	117·6	15·70		−5·3	H
,, ,, ..	,,	,,	116·1	16·35	=16·07	−1·4	,,
,, ,, ..	,,	,,	117·9	16·15		−2·6	,,
		Mean		16·58			
October 30 ..	A	10	114·9	16·65		+2·5	B
,, ,, ..	,,	,,	113·1	15·67	=16·10	−3·5	,,
,, ,, ..	B	11	110·7	15·98		−1·6	,,
,, ,, ..	,,	,,	114·6	15·88		−2·2	C
,, ,, ..	,,	,,	116·4	16·62	=16·12	+2·3	,,
,, ,, ..	A	10	125·7	15·85		−2·4	,,
,, ,, ..	,,	,,	115·8	17·00		+4·7	G
,, ,, ..	,,	,,	117·6	16·70		+2·8	,,
,, ,, ..	B	11	117·3	15·71	=16·41	−3·3	,,
,, ,, ..	,,	,,	113·7	16·24		0·0	,,
,, ,, ..	A	12	118·5	15·84		−2·5	D
,, ,, ..	,,	13	117·6	16·25	=16·27	0·0	,,
,, ,, ..	,,	,,	117·6	16·72		+3·0	,,
		Mean		16·24			

13·7 per cent. of the tests within 1 per cent. of the mean.

TABLE IV.—CANDLE TESTS ON PORTABLE PHOTOMETER.

Date. 1885.	Consumption of sp rm. Grains per hour.	Value ascribed to comparison flame.
January 6	118·3	16·21
,, ,, ...	117·3	16·24
,, ,, ...	111·4	16·34
,, ,, ...	111·0	16·18
,, 9	119·4	16·00
,, ,, ...	118·2	16·15
,, ,, ...	111·1	16·24
,, 19	120·6	16·56
,, ,, ...	115·2	16·74
,, ,, ...	121·2	16·80
,, 29	124·8	16·05
,, ,, ...	114·3	15·94
,, ,, ...	119·4	16·03
February 9	120·6	15·97
,, ,, ...	115·2	15·89
,, ,, ...	114·3	15·88

"CARCEL" LAMP.

This lamp, named after the inventor, was devised in 1800. The wick is annular, as first arranged by Argand. The oil used is refined colza, and is forced up to the wick from the reservoir by means of a small clockwork pump. The essential differences between this and the sperm oil lamp of the late Mr. Keates are—

1st.—Oil consumed.

2nd.—The size of the flame of the Carcel lamp is regulated by two things: first, the height of the wick; secondly, the height of the shoulder of the glass. With the Keates' lamp the height of the flame is regulated solely by the wick, the position of the glass being constant.

3rd.—The Carcel lamp does not provide for such an even and well regulated supply of air to the flame as is the case with the Keates' lamp. The wick of the Carcel stands unprotected save by the chimney, whilst that of the Keates is surrounded by a metallic cone, which directs the air currents upon the flame in a manner precisely similar to that of the cone in the improved Argand burners of Messrs. Sugg and Co. The effect of this arrangement is that the flame produced by the Keates lamp is absolutely steady, whilst that of the Carcel is continually oscillating, the flame being momentarily higher at one portion than another.

4th.—The illuminating power of the Carcel is about 9·5 candles, while that of the Keates is 16·0 candles.

For the purpose of showing the conditions under which this lamp must be used, I have extracted the following from M. Monnier's "Étude sur les Étalons

Photométriques." The conditions to be observed when testing with the Carcel lamp are by no means definite, as each lamp must first be tested before being used as a photometric standard. The rule, however, is that the height of the wick and chimney must be so arranged that the consumption of oil must be within the limits of 38 and 46 grammes per hour, but for exact experiments it is preferable to restrict these limits, and maintain the consumption between 40 and 44 grammes per hour. The light given by the lamp is corrected by simple calculation on the assumption that 42 grammes of oil per hour equals one Carcel.

The results of experiments made by MM. Audouin and Berard show that an increase in the height of the wick up to a certain point—10 millimetres—increases the consumption of oil as well as the intensity of light; and that beyond tnat point both the consumption of oil and the intensity diminish. Secondly, that the elevation of the constricted portion of the glass chimney tends to augment the consumption of oil in increasing ratio, but that there is a point where, the consumption still increasing, the intensity diminishes. Consequently there is a height of the glass which corresponds to the maximum illuminating power of the lamp.

For each experiment a new wick is necessary, which must be cut level with the wick-holder. The lamp, replenished with oil up to the level of the gallery, must be allowed to burn for half-an-hour before commencing the experiment.

The height of the wick must apparently be from 8 to 10 millimetres, and that of the shoulder of the glass about 7 millimetres above the wick, and that of the flame about 36 millimetres.

In order to ascertain the relative illuminating power of the Carcel lamp as compared with the English standard candle, I have made comparison experiments with both Pentane and Keates' lamp. The results obtained are fully stated in the tables, and show, 1st, that the Carcel lamp is by no means so steady in working as the Keates, only 39 per cent. of the tests being within 1 per cent. of the mean; 2nd, that the mean value of the Carcel is, by these tests, equal to 9·41 standard candles, which is a close approximation to the results of tests made by Mr. Sugg, in 1870, when he found the Carcel to be equal to 9·6 candles.

The tests made on the 7th, February show a most surprising uniformity in the results obtained with varying rates of consumption of oil. On that occasion two lamps were used alternately, each burning different samples of oil. No. 5 was from Paris, No. 2 was obtained in London. The consumption varied from 42·76 grammes to 48·30 grammes per hour, excluding the first test, which was obviously exceptional. The value ascribed to the comparison flame varied only from 1.725 to 1·751 Carcels. In the first case the consumption was 42·76 grammes, and in the latter 47·45 grammes per hour.

The samples of oil used and numbered 1 to 4 were obtained in London, and were from four separate refinings.

TABLE V.—CARCEL LAMP.

Compared with Pentane and Keates Lamp.

Date.	Oil and Lamp used. Lamp.	Oil.	Grammes consumed per hour.	Calculated value of Carcel flame 42 grammes per hour = 1 Carcel.	Value ascribed to comparison flame by Carcel.	Value ascribed to comparison flame by	Percentage variation of each test from mean.	Value of Carcel lamp in candles.
1885.						*Pentane.*		
Jan. 31	No. 1	No. 1	44·82	1·067	1·739	16·05	+0·1	
,, ,,	,, ,,	,, ,,	45·30	1·079	1·737	16·25	0·0	
,, ,,	,, ,,	,, ,,	46·10	1·097	1·733		−0·2	
,, ,,	,, ,,	,, ,,	46·30	1·102	1·719		−1·0	
,, ,,	,, ,,	,, ,,	46·41	1·105	1·691		−2·6	
,, ,,	,, ,,	,, ,,	43·80	1·043	1·804		+3·8	
				Mean ..	1·737	16·10		9·27
Feb. 7	No. 2	No. 5	48·83	1·163	1·803		+2·7	
,, ,,	,, ,,	,, ,,	48·30	1·150	1·746		−0·5	
,, ,,	,, 1	,, 2	43·27	1·030	1·735		−1·2	
,, ,,	,, ,,	,, ,,	43·06	1·025	1·737		−1·0	
,, ,,	,, 2	,, 5	47·45	1·130	1·751		−0·2	
,, ,,	,, 1	,, 2	43·06	1·025	1·734	*Pentane.*	−1·2	
,, ,,	,, 2	,, 5	47·60	1·133	1·756	16·64	0·0	
,, ,,	,, 1	,, 2	42·76	1·018	1·725	16·66	−1·7	
				Mean ..	1·755	16·65		9·49
Feb. 9.	No. 2	No. 5	45·34	1·080	1·841		+1·3	
,, ,,	,, ,,	,, ,,	44·78	1·066	1·813		−0·2	
,, ,,	,, ,,	,, ,,	45·68	1·083	1·830		+0·7	
,, ,,	,, 1	,, 3	39·82	0·948	1·763		−3·0	
,, ,,	,, ,,	,, ,,	42·76	1·018	1·878		+3·4	
,, ,,	,, ,,	,, ,,	40·81	0·972	1·798		−1·1	
,, ,,	,, 2	,, 5	44·12	1·050	1·891	*Pentane.*	+4·1	
,, ,,	,, ,,	,, ,,	43·69	1·040	1·872	16·79	+3·0	
,, ,,	,, ,,	,, ,,	45·34	1·079	1·863		+2·5	
,, ,,	,, ,,	,, ,,	44·78	1·066	1·812		−0·3	
,, ,,	,, ,,	,, ,,	44·88	1·068	1·811	16·94	−0·3	
,, ,,	,, ,,	,, ,,	44·66	1·063	1·797		−1·1	
,, ,,	,, ,,	,, ,,	45·00	1·071	1·768		−2·7	
,, ,,	,, 1	,, 4	40·72	0·969	1·764		−2·9	
,, ,,	,, ,,	,, ,,	40·72	0·969	1·755		−3·4	
				Mean ..	1·817	16·86		9·28
						Keates		
Feb. 10	No. 2	No. 5	44·01	1·048	1·776	*Lamp.*	−0·2	
,, ,,	,, ,,	,, ,,	43·37	1·033	1·755	17·13	−1·6	
,, ,,	,, 1	,, 4	40·63	0·967	1·756	17·18	−1·5	
,, ,,	,, ,,	,, ,,	41·76	0·994	1·846	17·07	+3·6	
				Mean ..	1·783	17·13	33) 44·1 1·34	9·61
							Mean.	9·41

32 per cent. of the tests within 1 per cent. of the Mean.

THE KEATES LAMP.

This lamp, the invention of the late Mr. T. W. Keates, was first described and illustrated in the "Journal of Gas Lighting" in March, 1869, at which time it was arranged to yield a light equal to 10 candles. Subsequently to that date the arrangement of the burner was altered, and the lamp made to yield a light equal to 16 candles. The inventor, in describing the arrangement, claimed that he was "in a position to propose a standard of light "which, if not perfect, at least surpasses not only the sperm candles, but also the "ordinary French lamp standard." With regard to the oil used in the Carcel lamp, Mr. Keates stated that he "believed that a worse or more uncertain material than "refined rape or colza oil could not have been proposed for burning as a standard "of light; and further on, that sperm oil is a natural production in the form in "which we have it; it is only filtered to separate from it the solid spermaceti with "which it is naturally mixed, and it never undergoes any chemical treatment, so "that its constitution is in no wise altered artificially. Various specimens re-"semble each other so closely that no difference can be detected in their manner of "burning, and what is of great importance, the specific weight of sperm oil is so far "removed from that of the other fat oils, that adulteration with inferior oil cannot "be carried on without being easily detected."

The well-known experience of the inventor of this lamp in connection with the oil industry, entitled him to speak with great weight upon this important point, and as his statements, made in 1869, have not been controverted, they may fairly be accepted as proved.

It will be unnecessary for me to describe the lamp more fully than to state that it is a modified form of the moderator lamp. When burning sperm oil at the rate of 925 grains per hour, with a 2-inch flame, the light emitted is equal to 16 candles. As with candles the consumption must be weighed and the necessary correction made for any variation from this rate, the operations being precisely similar to those with candles. A tabulated statement is furnished with each lamp, which reduces the calculations to a mere observation. If it is not deemed necessary to obtain results, say in preliminary experimental work, closer than half a candle, the observer can, after a little practice, adjust the height of the flame so nearly to the truth that weighing the oil, &c., is unnecessary. But for accurate work it is essential that the oil consumed should be weighed, and the necessary correction made. Messrs. Sugg & Co. have modified one form of the lamp by placing a screen having an aperture in front of the flame; the size of the aperture is regulated to pass light equal to two standard candles. Unlike the slot in Methven screen, this is horizontal. As will be seen by the tables, I have tried this arrangement, but cannot recommend it in preference to the full flame, although it doubtless has its advantages in simplicity; but, personally, I would prefer to adjust the flame to two inches, and assume that to be 16 candles, as above stated.

In the course of my experiments I have tried four separate lamps, each differing slightly from the others in minor points of construction. This, although at first sight a mistake, had decided advantages as enabling one to ascertain whether or not any slight variation in the manufacture of the lamps would affect the results obtained

from the burning of the same quantity of oil. I may say at once that no difference was found, although the lamps were submitted to most searching trials.

The lamp which I have termed the " Standard " was one which has been in use over ten years without repairs of any kind. It is the lamp which was used when the comparison tests with candles were made, and with which the rate of 925 grains of sperm consumed per hour was found to equal 16 candles. The lamp termed the " Old " lamp, was one which has been used from time to time, but differs from the " Standard," in that it gives a shorter and thicker flame; while that termed the " Small " lamp was only recently constructed; it is designed to contain only a small quantity of oil, sufficient for about three hours' burning. This lamp gives a flame longer and thinner than the " Standard." The fourth lamp is the one arranged with a screen to yield a light equal to two or five candles, as may be desired.

As the actual experiments conducted by myself under the direction of the late Mr. Keates in 1879, for the purpose of ascertaining the rate of consumption of oil required to produce a light equal to 16 standard sperm candles have not hitherto been published, I append them to this report. It will be observed on examination of this table that, of the 50 tests made, 26 were taken when the light yielded by the lamp was equal to or above 16·5 candles, whilst 24 were taken when it was below 16·5 candles; that is, if the observations counted are those in which the light is calculated for consumption of oil. It curiously happens, as these tests were made in succession and on various days without selection of any kind, that of the 50 tests 25 show a greater consumption than 925 grains of oil per hour required to equal 16·0 candles, and 25 show a less consumption than that quantity for effecting the same object. Considering the variability of candles, it is difficult to refrain from the conclusion that these results afford a strong argument in favour of the perfect steadiness of the light yielded by the lamp.

For the purpose of ascertaining whether the different lamps above referred to yielded equal volumes of light, I have made four series of tests with the following results. In the first of these, two lamps, the " Standard " and the " Small " lamp, were compared together. The mean of three tests with the first gave a value of 14·34 (Table VII.) to the comparison gas flame, the greatest difference between the three tests being 0·22 candle, while the second lamp gave a mean of 14·47, the greatest difference in these three tests being 0·24 candle. In the second series the " Standard " lamp gave a value of 13·32 candles, the greatest difference in the three tests being 0·27 ; and the " Small " lamp gave 13·42, one test only.

In the third series the tests were in four groups, the same lamps being employed alternately. The average of the whole was 14·88 candles ; group No. 1, " Small " lamp, gave 14·70 candles ; group No. 2, " Standard " lamp, gave 14·96 ; group No. 3, " Standard " lamp, gave 14·88 ; group No. 4, " Small " lamp, gave 14·91 candles.

In the fourth series the " Standard," " Old," and the " Small " lamps were used. The first gave 15·11, the second 15·09, and the third lamp 15·21 candles; the average of the whole being 15·15 candles.

The question of the variability in the light yielded when different samples of oil are used is a most important one. I have, therefore, tried three different samples of

oil. The first was obtained from firm A, and had been in the laboratory for over twelve months; the second was supplied by the same firm a few days before the tests were made; the third sample was newly purchased from firm B. I have also used wicks obtained at widely different dates. As both the wicks and oils were indifferently used in the above experiments, it will be seen that there can be no objection to the Keates' lamp being adopted as a standard of light on the ground of variability from these causes.

The next point which it appeared to me important to ascertain was whether the lamp is capable of yielding constant results during the whole period of burning. I therefore made two series of tests (Table VIII.) The first of these was commenced at 4.10 p.m. on Nov. 12, 1884, and continued to 7.20 p.m.; the lamp was then retrimmed and charged with an additional quantity of oil, and the testing resumed and continued to 9.30 p.m. The comparison gas flame employed was obtained by burning stored gas from the 100 feet holder, the flame in the "Standard" burner being 3½ inches in height. To ensure uniformity only a portion of this flame was used, the light from the top and bottom portions being cut off by means of screens. The results are given in the tables, and show a most remarkable constancy. Twenty complete observations were made, of which twelve were within 0·1 candle of the mean. Of the remainder, three are decidedly exceptional, but nevertheless are valuable as indicating the importance of proper ventilation in the testing-room. Test No. 6 was made at 6.40 p.m. after three persons had been continually at work in the photometer room, a small one, for two hours and a half. There being no proper arrangements for ventilation the temperature of the room had risen to an unpleasant extent, and the vitiation of the atmosphere was decidedly noticeable. The eighth test indicating a still higher result, the window was thrown open for a time, sufficient to thoroughly change the atmosphere of the room. When this had been accomplished, another test, with the lamp precisely in the same condition as before, was made, and a fair result obtained. During the remainder of the evening the window was left partially open; the result being that, of eleven tests, the *maximum* variation was 0·3 candle.

The second set of tests for "constancy," series No. 2, Table VIII., gave equally satisfactory results. Of 16 tests, 12 were within 0·1 candle of the mean of the whole. Since these tests have been made I have had the lamp burning continuously for eight hours with good results.

The next set of tests, Table IX., was instituted for the purpose of ascertaining the behaviour of the lamp when used by different operators. This series was divided into two parts; the first was conducted between 11.40 a.m. and 2.40 p.m., and the second between 4.12 p.m. and 5.7 p.m. Five observers took part in the morning, and six in the afternoon series. The details obtained are given in the tables, and show a most satisfactory result. Later in the evening three observers made tests with the "Standard" and "Screened" lamps with remarkable uniformity of results,

TABLE VI.—THE KEATES LAMP.

Experiments to ascertain the rate of consumption of Sperm Oil required to produce a light equal to 16 Standard Candles.

No.	Date.	Hour of Day.	Duration of test.	Grains of Oil actually consumed.	Grains of oil consumed per HOUR.	Observed light yielded by lamp, in corrected candles.	Actual light yielded by lamp, corrected for oil consumed. 925 grains per hour = 16 Candles.	Calculated sperm consumption to give 16-candle light. Grains per hour.
	1879.	p. m.	m. s.					
1	March 19	2.15	14. 8	230	977	16·03	16·90	974
2	,, ,,	2.30	11.37	200	1033	17·16	17·86	963
3	,, ,,	2.45	11.24	200	1053	17·42	18·20	967
4	,, 20	12.0	11.13	200	1070	17·01	18·50	1006
5	,, ,,	12.15	11.14	200	1068	16·68	18·47	1024
6	,, ,,	12.40	11.19	200	1060	17·29	18·34	982
7	,, 21	11.30	11.30	200	1043	16·57	18·04	1007
8	,, ,,	12.0	11.45	200	1021	17·03	17·66	959
9	,, ,,	12.30	11.25	200	1051	18·39	18·17	914
10	,, ,,	1.10	12.55	230	1069	18·51	18·50	924
11	,, ,,	3.30	11.35	200	1036	18·74	17·92	884
12	,, ,,	4.0	13.42	250	1095	18·87	18·80	928
13	April 1	11.0	13. 8	200	913	17·50	15·80	834
14	,, ,,	11.30	18.12	300	989	18·84	17·10	840
15	,, ,,	3.0	20.36	300	873	14·10	15·10	1061
16	,, ,,	4.0	13.58	200	859	14·20	14·85	968
17	,, 2	11.0	13.40	200	876	15·75	15·18	890
18	,, ,,	11.30	12.45	200	941	17·05	16·28	883
19	,, ,,	12.0	12.40	200	943	17·92	16·38	843
20	,, ,,	12.20	11.55	200	1007	17·62	17·41	915
21	,, ,,	12.35	12.26	200	965	16·81	16·58	919
22	,, ,,	12.50	11.44	200	1020	17·05	17·68	958
23	,, ,,	1.15	12.49	200	936	16·87	16·19	888
24	,, 4	11.15	13.12	200	909	15·42	15·72	943
25	,, ,,	11.30	12.29	200	961	16·31	16·62	943
26	,, ,,	12. 0	12.43	200	942	16·80	16·32	897
27	,, ,,	12.15	12.12	200	984	17·12	17·00	920
28	,, ,,	12.30	12.20	200	973	17·12	16·82	909
29	,, ,,	12.45	15. 7	250	992	16·44	17·20	965
30	,, ,,	2.50	12.38	200	948	17·81	16·42	852
31	,, ,,	3.15	15.35	250	962	18·32	16·60	840
32	,, ,,	4.0	25. 3	400	959	18·38	16·58	838
33	,, 5	11.30	12.26	200	974	17·30	16·68	901
34	,, ,,	12.0	12.33	200	956	16·17	16·52	946
35	,, ,,	12.20	12.32	200	957	16·48	16·55	930
36	,, ,,	12.45	12. 3	200	994	16 53	17·22	962
37	,, ,,	1.0	12.33	200	956	16·38	16 52	934
38	,, ,,	1.10	13. 0	200	923	16.73	15·96	883
39	,, ,,	1.30	12.50	200	935	16·80	16·17	890
40	,, 7	12.40	14. 5	200	852	15·48	14.73	886
41	,, ,,	1.0	13.30	200	885	15·64	15.37	912
42	,, ,,	1.30	13.21	200	899	15·40	15·54	934
43	,, ,,	1.40	12.37	200	951	15·95	16·44	954
44	,, ,,	2.0	13. 4	200	919	16·63	15·88	884
45	,, ,,	3.0	12.31	200	959	15·74	16·58	975
46	,, ,,	3.15	13. 7	200	915	15·37	15·82	952
47	,, ,,	3.30	12.58	200	925	15·26	16·00	970
48	,, 8	11.45	12.50	200	935	15·88	16·17	942
49	,, ,,	12.0	12.49	200	936	17·11	16·19	876
50	,, ,,	12.40	14. 0	200	857	15·10	14.82	908
							Average	925

TABLE VII.—THE KEATES LAMP.

Comparison of Lamps.

Date.	Quantity of oil consumed. Grains per hour.	Calculated illuminating power of lamp.	Value ascribed to comparison gas flame.		Percentage variation from mean.	Remarks.
				SERIES	No. 1.	
1884.						
Nov. 1	937	16·21	14·52		+0·8	Standard lamp with oil
,, ,,	927	16·04	14·20	=14·34	−1·5	A. Old sample.
,, ,,	929	16·08	14·30		−0·8	,, ,, ,,
,, ,,	904	15·64	14·30		−0.8	Small lamp with oil A.
,, ,,	873	15·10	14·57	=14·47	+1·1	New sample.
,, ,,	906	15·68	14·54		+0·9	,, ,, ,,
		Mean	14·41			
				SERIES	No. 2.	
Nov. 1	953	16·46	13.47		+0·9	Standard lamp with oil
,, ,,	999	17·29	13·20	=13·32	−1·1	A. New sample.
,, ,,	876	15·15	13·30		−0·4	,, ,, ,,
,, ,,	904	15·64	13.42		+0·5	Small lamp.
		Mean	13·35			
				SERIES	No. 3.	
Nov. 5	877	15·18	14·60		−1·9	Small lamp with oil A.
,, ,,	881	15·25	14·61	=14·70	−1·9	Old sample.
,, ,,	920	15·92	14·90		0·0	,, ,, ,,
,, ,,	986	17·05	14·83		−0·4	Standard lamp with oil
,, ,,	994	17·20	14·91		+0·1	A. Old sample.
					Wick	adjusted.
,, ,,	932	16·12	15·41		+3·4	,, ,, ,,
,, ,,	930	16·08	15·09	=14·96	+1·3	,, ,, ,,
,, ,,	947	16·38	14·93		+0·2	,, ,, ,,
,, ,,	952	16·46	14·83		−0·4	,, ,, ,,
,, ,,	942	16·30	15·03		+0·9	,, ,, ,,
,, ,,	969	16·77	15·09		+1·3	,, ,, ,,
,, ,,	967	16·73	*14·65		−1·6	Standard lamp with oil
,, ,,	981	16·96	14·75		−0·9	B.
,, ,,	981	16·96	14·87	=14·88	−0·1	,, ,, ,,
,, ,,	994	17·20	14·83		−0·4	,, ,, ,,
,, ,,	964	16·68	14·93		+0·2	,, ,, ,,
,, ,,	967	16·55	14·91	14·91	+0·1	Small lamp with oil B.
		Mean	14·89			
				SERIES	No. 4.	
Nov. 6	962	16·64	15·11		−0·3	Standard lamp.
,, ,,	986	17·05	15·09		−0·4	Old lamp.
,, ,,	947	16·38	15·36	=15·21	+0·7	Small lamp.
,, ,,	927	16·04	15·06		−0·6	,, ,, ,,
		Mean	15·15			

71 per cent. of the tests within 1·0 per cent. of the mean.

* Tests commenced within 20 minutes of lighting lamp.

TABLE VIII.—THE KEATES LAMP.

Constancy of Light.

"Standard" Lamp.

Date.	Time.	Quantity of oil consumed. Grains per hour.	Calculated illuminating power of lamp.	Value ascribed to comparison gas flame	Percentage variation from mean.	Remarks.
			SERIES	No. 1.		
1884.	P.M.					
Nov. 12	4·10	947	16·38	15·21	−0·5	
,, ,,	4·25	937	16·21	15·21	−0·5	
,, ,,	4·35	968	16·75	15·29	0·0	
,, ,,	5·0	947	16·38	15·55	+1·8	Lamp flame re-adjusted.
,, ,,	5·15	939	16·25	15·35	+0·4	
,, ,,	6·40	930	16·08	15·76	+3·1	
,, ,,	6·50	932	16·12	15·21	−0·5	
,, ,,	7·0	947	16·38	15·90*	+3·%	
,, ,,	7·20	962	16·64	15·55	+1·8	Window opened.
	Lamp	re-trimmed and charged with		fresh oil.		
,, ,,	8·10	986	17·05	15·22	−0·5	
,, ,,	8·20	987	17·08	15·41	+0·8	Lamp flame adjusted.
,, ,,	8·30	972	16·81	15·10	−1·3	Lamp flame adjusted.
,, ,,	8·40	988	17·10	15·26	−0·2	
,, ,,	8·50	975	16·87	15·28	0·0	Lamp flame adjusted.
,, ,,	9·0	981	16·96	15·22	−0·5	
,, ,,	9·5	957	16·55	15·35	+0·4	Lamp flame adjusted.
,, ,,	9·12	962	16·64	15·12	−1·1	
,, ,,	9.20	960	16·60	15·13	−1·0	
,, ,,	9·24	966	16·70	15·10	−1·3	
,, ,,	9·28	972	16.82	15·23	−0·4	
					* Left out	in calculating mean.
			Mean..	15·29		
			SERIES	No. 2.		
1884.	A.M.					
Nov. 13	11·10	981	16·96	15·09	+1·6	
,, ,,	11·20	996	17·24	14·92	+0·5	
,, ,,	11·27	987	17·08	14·95	+0·7	Lamp flame adjusted.
,, ,,	11·35	964	16·68	14·78	−0·7	Lamp flame adjusted.
,, ,,	11·45	976	16·89	14.65	−1·3	
,, ,,	11·57	962	16·64	14·96	+0·7	Lamp flame adjusted.
	P.M.					
,, ,,	12·6	976	16·89	14·73	−0·8	
,, ,,	12·15	969	16·77	14·95	+0·7	
,, ,,	12.25	991	17·14	14 98	+0·9	
,, ,,	Lamp	re-trimmed and charged with		fresh oil.		
,, ,,	2·5	964	16·68	14·93	+0·5	
,, ,,	2·20	967	16·73	14·78	−0·5	
,, ,,	2·50	966	16·70	14·79	−0·4	
,, ,,	3·15	943	16·30	14·80	−0·3	
,, ,,	3·30	954	16·50	14·73	−0·8	
,, ,,	3.40	960	16·60	14·91	+0·4	
,, ,,	3·55	957	16·55	14·88	+0·2	
			Mean..	14·86		

77 per cent. of the tests within 1·0 per cent. of the mean.

TABLE IX.—THE KEATES LAMP.

Observations by different Operators.

Date.	Quantity of Oil consumed. Grains per hour	Calculated illuminating power of lamp.	Value ascribed to comparison gas flame.	Percentage variation from mean.	Observer.
		"Standard" Lamp.			
1884					
Nov. 19	967	16·73	13·98	+1·8	C
,, ,,	982	16·98	13·95	+1·5	G
,, ,,	973	16·84	13 61	−0·9	,,
,, ,,	984	17·02	13·60	−1·0	,,
,, ,,	969	16·77	13·46	−2·0	,,
,, ,,	994	17·20	13·85	+0·8	C
,, ,,	943	16·30	13·80	+0 4	I
,, ,,	954	16·50	13·86	+0·9	J
,, ,,	947	16·38	13·60	−1·0	E
		Mean ..	13·74		
,, ,,	925	16·00	13 38	+1·5	B & L
,, ,,	918	15·88	13·25	+0·5	D
,, ,,	930	16·08	12·86	−2 5	A
,, ,,	914	15·80	12·85	−2·5	F
,, ,,	940	16·25	13·10	−0·7	A
,, ,,	950	16·42	13·46	+2 1	H
,, ,,	954	16·50	13·30	+0·8	F
		Mean ..	13·19		
		Readings with Screened Lamp adjusted for five candles.			
Nov. 19	..	..	13·00	.. *	K
,, ,,	..	..	13·20	..	I
,, ,,	..	..	13·00	..	E
,, ,,	..	..	13·00	..	,,
,, ,,	..	..	12 95 = 13·03	..	,,
,, ,,	..	..	13·20	..	,,
,, ,,	..	..	12·95	..	,,
,, ,,	..	..	13·05	..	,,
	Same Lamp	adjusted for	*two* candles.		
,, ,,	..	..	13·10	..	I
,, ,,	..	..	13 00	..	E
,, ,,	..	..	12 95 = 13·00	..	K
,, ,,	..	..	12·90	..	E
,, ,,	..	..	13·00	..	K
,, ,,	..	..	13·00	..	I
	16 C.	"Standard"	Lamp.		
,, ,,	934	16·16	13·13	−0·8	
,, ,,	1003	17·34	13·28 = 13·23	+0·5	
,, ,,	989	17·10	13·30	+0·5	
		Mean ..	13·23		

58 per cent. of the tests with "Standard" Lamp within 1·0 per cent. of the mean.

* Not included in mean or percentages.

Mr. A. G. VERNON HARCOURT'S PENTANE, or AIR-GAS STANDARD.

Mr. Harcourt introduced this form of proposed Standard to the notice of the Physical and Chemical Sections of the British Association at their meeting held at Plymouth, August 17th to 20th, 1877. On the 8th April, 1879, Mr. Harcourt forwarded to the Board of Trade a letter accompanied by a tabulated statement of a series of tests made with candles and the new standard. In this letter Mr. Harcourt states that he found a difference of 6 to 7 per cent. in the light emitted from the candles of the two makers to whom I have already referred. In consequence of this communication the Board of Trade appointed the Committee previously mentioned, who unhesitatingly recommended the adoption of Mr. Harcourt's Pentane standard.

The chief points for consideration in connection with this unit are—1st. Possibility of the production of Pentane of constant or practically constant composition. 2nd. The capability of Pentane to produce various samples of gas of equal illuminating power. 3rd. The production of a flame of unvarying size and luminosity.

The first of these points may fairly be accepted as proved. The researches of Mr Harcourt have been so extensive and exhaustive that they leave little to be desired. As it is important that the nature of this standard should be thoroughly understood, I have extracted the following from Mr. Harcourt's paper, read before the British Association :—" For the standard combustible I employ a mixture of air with that " portion of American petroleum which, after repeated rectifications, distils at a " temperature not exceeding 50 deg. C. This liquid consists almost entirely of " pentane, the fifth member of the series of paraffins. I have made three or four " analyses of the liquid, which, though, they scarcely distinguish between pentane " and the adjoining hydrocarbons of the same series—the proportion of carbon to " hydrogen being in pentane, carbon 83·3, hydrogen 16·7, and in hexane, carbon 83·7, " hydrogen 16·3—would reveal the presence of small quantities of hydrocarbons " richer in carbon. I have also determined the vapour density of the liquid. The " density of gaseous pentane, compared with hydrogen, is 36; that of hexane 43. " I find the vapour density of the liquid, distilled twice below 50 deg. to be 37. The " lighter portions of purified American petroleums have been carefully examined by " Ronalds, Cahours, Warren, Schorlemmer, and other chemists, and have been " found to consist of the following hydrocarbons :—tetrane, boiling between " 0 deg. and 4 deg., and having a specific gravity at 0 deg. of 0·6; two isomeric " pentanes, one boiling at 30 deg., the other at 37 deg., and having at 17 deg. a " a specific gravity of 0.626 (Schorlemmer), 0·628 (Cahours), the proportion of " which appears to vary, since the hydrocarbon separated by Cahours boiled at " 30 deg., while Schorlemmer states that the pentane in the samples examined " by him consisted almost of the variety boiling between 37 deg. and 39 deg.; " hexane, which boils at 68 deg. C., and has a specific gravity at 16 deg. C., of " 0·669. The liquid I use has a specific gravity which has only varied in different " samples between 0·6298 and 0·63, except in one case, in which, probably owing " to the temperature of distillation having been allowed to rise too high, it was " 0·631. It would not be difficult, by rectifying at 40 deg. to obtain almost absolutely " pure pentane. But I do not think it necessary to limit the distillation to this " temperature, because the yield at 50 deg. is rather larger, and it seems hardly " possible that the admixture of a small and nearly constant proportion of a sub- " stance so little different as hexane can affect the quality of the liquid as a

" combustible. Also I find, having distilled ten or twelve samples of the liquid, " using about three litres each time, that I get a constant specific gravity."

The second point, " the capability of pentane to produce various samples of gas of equal illuminating power," has received very careful attention. During the course of my experiments I have used eight samples of pentane obtained from as many distillations. The system I employed was to make samples of pentane gas in each of two holders, and then to test a comparison flame with them. The first and second volumes of gas made in the 5-feet holder were used to test the apparatus. The third make was used as a standard. and compared with the first gas made over clean water in the 11-feet holder. As might be expected these two samples gave slightly varied results, but only to the extent of 0·2 candle on 14·0 candle gas. The samples subsequently prepared gave identical results.

The only difficulty met with in the preparation of the air-gas was with the first few samples. The method of introducing the liquid pentane into the holder, as submitted to me by Mr. Harcourt, was to pass the bent end of a pipette to the bottom of a syphon tube sealed with water. The long limb of this syphon passed through a cork fitted tightly in the top of the bell of the holder. On opening the stopcock of the pipette the pentane passed down through the tube, and taking the direction of the bent end, rose upward through the column of water and passed over the top bend of the syphon into the bell. Finding this system inconvenient and liable to accidents, I replaced it with another of more simple and reliable character. I cut off the bent end of the pipette and ground it accurately into a second shorter and stouter tube provided with a stopcock; this short tube I fitted into the crown of the bell of the holder by means of a tightly-fitting india-rubber cork. The charging of the holder with pentane, without either letting air into the holder or losing pentane, thus becomes a matter of absolute certainty. I first fill the pentane pipette in the usual manner, then firmly fit the ground end into the open end of the tube in the bell of the holder, and open the two stopcocks, viz., the one in the short tube and the one on the pipette, when the pentane runs through the tube into the holder without hesitation or possibility of loss. When the pipette is nearly empty I close the open end at the top with the forefinger, and warm the bulb of the pipette, the warmth of the hand being sufficient, when the pentane vapour, becoming expanded, drives the last portions of pentane into the holder. The stopcock in the short fixed tube, which is ground perfectly gas-tight, is closed, and the pipette removed.

The third point is one which has been very much questioned. The strongly expressed opinions of Messrs. Heisch and Hartley, which I have quoted, throw great doubt on it. On the other hand, the numerous results published by Mr. Harcourt and the Board of Trade Committee are decidedly against the views expressed by those gentlemen. In view of the conflict of evidence between such experienced photometrists, I have deemed it necessary to take special care to ascertain the facts.

As I have stated, the apparatus employed by me was fitted up under the immediate supervision of Mr. Harcourt at my request, in order that there might be no doubt as to the arrangements being in perfect accordance with the inventor's specifications. From the first start to the end of my experiments the whole of the tests were made with great facility. In fact I was agreeably surprised at the simplicity and convenience experienced. It has been stated, and seems to be

generally accepted, that the Methven screen, the standard to be next considered, is the most simple of any of those proposed. So far as my personal experience goes, I do not think that the few minutes which would be occupied in practice every ten days or so in making fresh samples of pentane gas would, in the end, be more trouble than the daily cleaning of the lamp glasses used with the Methven screen.

The results of the tests tabulated in Table X. made to ascertain the possibility of producing various samples of air-gas of equal illuminating power, are quite in accordance with Mr. Harcourt's statement that pentane gas first made over fresh water may give results slightly varying from that made in a holder which has been in use for a short time. The earlier samples of pentane gas made were not altogether satisfactory in consequence of the difficulty met with in introducing the liquid pentane into the holder; but subsequently, after the introduction of the modified form of pipette, the results were decidedly better, and those obtained when comparing different samples together were practically identical. The series of tests made by six observers on the 17th December, Table XI., most of them using pentane for the first time, are evidence of the difficulty first met with when reading by such a low standard of comparison as one candle. After a little practice this is, to a great extent overcome, it is true; but should this unit be adopted as a legal standard it would be a great advantage to employ two flames in place of the one recommended by the inventor.

The next series of tests, made to ascertain the possible variation due to repeated adjustment of the air-gas flame, gave decidedly favourable results. The tabulated statement (Table XII.) shows that the adjustment of the flame, although at first requiring a little practice, is a matter of certainty.

The important statements made by Messrs. Heisch and Hartley as to the unsteadiness of the pentane flame have received great attention. I have tried all that is possible to vary the height of the flame by any means likely to accidentally affect it. I have let heavy weights fall on the floor of the testing-room; shut both inner and outer doors violently; the wall of the room has been struck; in fact, everything done, short of damaging the premises, to test the steady burning of the flame. Beyond a momentary leap at the instant of concussion, no effect whatever was produced; the flame burnt steadily, and the readings were the same after the experiment as they were before. I am not aware that my photometer room is of a peculiarly solid construction, or subject to less vibration than those at the testing-stations. The only conclusion I can therefore come to is that the results obtained by Messrs. Heisch and Hartley are not of the nature of those which might be looked for in practice.

Mr. A. G. VERNON HARCOURT'S PENTANE.

TABLE X.—Experiments made to ascertain the possibility of the production of various samples of gas of equal illuminating power.

Date when gas was Made.	Date when gas was Used.	Holder used.	Volume of air-gas made from 9 cubic inches Pentane.	Value ascribed to compari-on flame.		Percentage variation from mean of results.
Third quantity of gas made in 5ft. holder, against first quantity made in 11 ft. holder.						
1884. Nov. 27	1884 Dec. 11	5 ft	4·04	14·07		+0·7
Dec. 10	Dec. 11	11 ft.	4·07	13·87		−0·7
			Mean	13·97		
Nov. 27	Dec. 12	5 ft.	As above	14·60		+0·6
,,	,,	,,	,,	14·65	=14·63	+0·9
,,	,,	,,	,,	14·63		+0·8
Dec. 10	,,	11 ft.	,,	14·41		−0·6
,,	,,	,,	,,	14·41	=14·41	−0·6
,,	,,	,,	,,	44·42		−0·7
			Mean	14·52		
Nov. 27	Dec. 13	5 ft.	As above	15·30		+1·9
Dec. 10	,,	11 ft.	,,	14·83		−1·6
			Mean	15·06		
Dec. 16	Dec. 18	5 ft.	4·09	11·87		0·0
,, 17	,,	11 ft.	4·05	11·87		0·0
			Mean	11·87		
Dec. 17	Dec. 31	11 ft.	4·05	16·45		−0·6
,,	,,	,,	,,	16·46	=16·44	−0·5
,,	,,	,,	,,	16·42		−0·7
Dec. 16	,,	5 ft.	4·09	16·60		+0·4
,,	,,	,,	,,	16·65	=16·63	+0·7
,,	,,	,,	,,	16·65		+0·7
			Mean	16·54		
	1885					
Dec. 17	Jan. 21	11 ft. (Transferred to 5 ft.)	4·05	15·45		+0·1
1885 Jan. 19	,,	11 ft.	3·96	15·43		−0·1
			Mean	15·44		
Jan. 28	Jan. 29	5 ft.	4·11	15·65		−0·5
,,	,,	,,	,,	15·70		−0·2
,,	,,	11 ft.	4·08	15·90		+1·1
,,	,,	,,	,,	15·75		+0·1
,,	,,	5 ft.	4·11	15·72		−0·1
,,	,,	,,	,,	15·70		−0·2
,,	,,	11 ft.	4·08	15·70		−0·2
,,	,,	,,	,,	15·70		−0·2
			Mean	15·73		
Jan. 28	Jan. 30	5 ft.	4·11	16·15		0·0
,,	,,	11 ft.	4·08	16·15		0·0
			Mean	16·15		

TABLE X.—MR. A. G. VERNON HARCOURT'S PENTANE—*Continued.*

Date when gas was Made.	Date when gas was Used.	Holder used.	Volume of air-gas made from 9 cubic inches Pentane.	Value ascribed to comparison flame.	Percentage variation from mean of results.
Jan. 31	Feb. 2	11 ft.	4·05	16·00	−0·4
,,	,,	,,	,,	16 00	−0·4
,,	,,	,,	,,	16 05	−0·1
,,	,,	5 ft.	4·11	16·10	+0·3
,,	,,	,,	,,	16·10	+0·3
,,	,,	,,	,,	16·00	−0·4
,,	,,	11 ft.	4·05	16·10	+0·3
,,	,,	,,	,,	16·05	−0·1
,,	,,	,,	,,	16·13	+0·4
,,	,,	5 ft.	4·11	16·03	−0·2
,,	,,	,,	,,	16·06	0·0
,,	,,	,,	,,	16·05	−0·1
			Mean	16·06	
Jan. 31	Feb. 3	5 ft.	4·11	16·00	+0·6
,,	,,	,,	,,	15·90	−0·1
,,	,,	,,	,,	15·90	−0·1
Feb. 2	,,	11 ft.	4·08	15·90	−0·1
,,	,,	,,	,,	15·87	−0·3
,,	,,	,,	,,	15·90	−0·1
			Mean	15·91	
Feb. 3	Feb. 7	5 ft.	4·11	16·60	−0·3
,,	,,	,,	,,	16·70	+0·3
,,	,,	,,	,,	16·63	−0·1
Feb. 2	,,	11 ft	4·08	16·70	+0·3
,,	,,	,,	,,	16·70	+0·3
,,	,,	,,	,,	16·60	−0·3
			Mean	16·65	

94 per cent. of the tests within one per cent. of the mean.

TABLE XI.—MR. A. G. VERNON HARCOURT'S PENTANE.
Observations by different Operators.

Date.	Value ascribed to Comparison flame.	Percentage variation from mean.	Observer.
1884.			
December 17	15·75	−1·4	
,, ,,	16·05	+0·5	
,, ,,	16·26	+1·8	A
,, ,,	16·06	+0·6	,,
,, ,,	15·98	0·0	,,
,, ,,	15·61	−2·2	B
,, ,,	15·62	−2·2	,,
,, ,,	16·28	+2·0	,,
,, ,,	16·28	+2·0	F
,, ,,	16·54	+3·5	,,
,, ,,	16·00	+0.2	C
,, ,,	16·08	+0·7	,,
,, ,,	16·01	+0·2	D
,, ,,	16·03	+0·4	,,
,, ,,	15·45	−3·2	C
,, ,,	15·50	−2·9	D
	Mean 15·97		

44 per cent. within 1·0 per cent. of the mean.

TABLE XII.—MR. A. G. VERNON HARCOURT'S PENTANE.

Experiments made to ascertain the possible variation due to repeated adjustment of the air-gas flame to 2½in. in height. The observations were made by two observers, making alternate tests.

Date.	Consumption of pentane gas. Cubic feet per hour.	Value ascribed to comparison flame.	Percentage variation from mean.
1884.			
November 26	0·500	15·90 *	..
,, ,,	0·480	16·65	+0·6
,, ,,	0·490	16·55	0·0
,, ,,	0·495	16·63	+0·4
,, ,,	0·500	16·40	−0·9
,, ,,	..	16·60	+0·2
,, ,,	..	16·55	0·0
		Mean 16·56	
November 27	0·500	16·60	0·0
,, ,,	0·480	16·60	0·0
		Mean 16·60	
November 29	0·485	16·05 *	..
,, ,,	0·485	15·60	+0·4
,, ,,	0·480	15·50	−0·3
,, ,,	0·480	15·55	+0·1
,, ,,	0·480	15·50	−0·3
		Mean 15·54	
December 12	0·494	14·60	−0·2
,, ,,	0·481	14·65	+0·2
,, ,,	0·485	14·63	0·0
		Mean 14·63	
December 12	0·619 (first gas made over clean water)	14·41	0·0
,, ,,	0·594	14·41	0·0
,, ,,	0·594	14·42	0·0
		Mean 14·41	
December 16	..	14·25	+0·6
,, ,,	..	14·05	−0·8
,, ,,	..	14·10	−0·4
,, ,,	..	14·25	+0·6
,, ,,	..	14·18	+0·1
		Mean 14·16	
1885.			
January 1	0·490	15·33	+0·5
,, ,,	0·490	15·19	−0·5
		Mean 15·26	

100 per cent. of the tests within 1·0 per cent. of the mean.

* Left out of calculations as obviously incorrect.

MR. A. G. VERNON HARCOURT'S PENTANE LAMP.

This lamp has been devised by Mr. Harcourt for the purpose of overcoming the objection to the air-gas standard that it is not portable, and involves expensive apparatus.

Unfortunately the lamp was received by me so recently as to preclude my submitting it to such a thorough examination as I should have liked to have done. The lamp which I have had an opportunity of trying was an experimental one, and was not fitted with the delicate regulating adjustments which it is proposed by the inventor to adopt, but such as had been arranged gave sufficient indications to show that, in the hands of the accomplished inventor, it will no doubt be brought to much greater perfection.

At first the indicated value of the comparison flame when tested by the lamp was nearly a candle less than that shown by the air-gas flame, but after the regulating aperture of the lamp had been enlarged the results were very concordant. Mr. Harcourt has arranged a modified form of the lamp for the purpose of protecting the flame from atmospheric currents. In this form the lamp may be placed in a strong draught without causing any variation in the character of the flame, but the tests show that the interposition of the chimney cuts off an appreciable volume of light, the value of the comparison flame being enhanced by a third of a candle, with the further disadvantage that the quantity of light furnished by the lamp may be varied according to the character of the glass chimney used, and even the side of the glass turned towards the photometer disc. For rough outdoor work these variations may not be of so much moment, but for accurate estimations I do not think that the glass chimney is advisable.

TABLE XIII.—PENTANE LAMP.

Date.	Standard flame used.	Value ascribed to comparison flame.	Remarks.
1885.			
Feb. 12.	Lamp flame unprotected ..	15·65	
,, ,,	,, ,, ..	15·68	
,, ,,	Lamp flame protected by chimney	15·90 16·10	Chimney turned half round.
,, ,,	,, ,, ,,	15·90	Chimney again turned half round.
,, ,,	Air gas flame for comparison ..	16·77	
,, ,,	,, ,, ,, ..	16·65	
,, ,,	Lamp flame unprotected ..	15·80	

The regulating aperture of the lamp was enlarged, and the following tests made:—

Feb. 16	Lamp flame unprotected ..	15·82	
,, ,,	,, ,, ,, ..	15·80	
,, ,,	,, ,, ,, ..	15·80	
,, ,,	Air gas flame for comparison ..	15·84	
,, ,,	,, ,, ,, ..	15·92	
,, ,,	,, ,, ,, ..	15·82	
,, ,,	,, ,, ,, ..	15·77	

MR. METHVEN'S SCREEN.

Mr. Methven introduced this method of obtaining a light of constant illuminating power in 1878, when he read a paper on the subject before the British Association of Gas Managers. The arrangement is exceedingly simple, consisting "of an "upright rectangular metallic plate or screen, having an horizontal flange or "bracket, upon which a Standard London argand burner is fixed, the latter being "supplied with gas through a plug or nosepiece projecting downwards. The upright "plate has a slot or hole above the flange or bracket, and this hole is covered by a "thin silver plate, having a vertical slot of such dimensions as to allow of the "passage of as much light as equals that afforded by two average standard sperm "candles when the Argand burner is delivering sufficient gas to give a flame 3 inches "in height." Finding that this arrangement was to be depended upon when gas of only ordinary quality was used, Mr. Methven experimented with "carburetted" gas, *i.e.*, gas enriched with hydrocarbons. For this purpose he adopted the same light petroleum spirit as Mr. Harcourt uses, viz., pentane. He found—1st, "that "all the carburetted gases were too rich to be burnt properly from a standard "argand, furnished with a 6 by 2 chimney, with a greater flame length than 2½ "inches; and, 2nd, that with that length of flame the amount of light yielded was "constant and altogether independent of the actual illuminating power of the coal "and cannel gases employed." Mr. Methven does not, however, use the entire flame obtained after carburation, but has arranged an aperture similar to that for the plain gas, but shorter and wider, and claims that the new arrangement is correct for all qualities of gas.

The Board of Trade Committee rejected this arrangement in its original form The idea of carburetting the gas may be looked upon as an outcome of their report, as Mr. Methven adopted the new method to meet the objections raised against the plain gas screen.

I have made three sets of tests with this screen; the first (Table XIV.) for the purpose of ascertaining whether the same results are obtainable when the original arrangement with plain 16·0 candle gas is used as when the carburetted gas is burnt. The tests on the 1st January (Table XIV.) were made by Messrs. Heisch, Hartley, Methven, and myself. On this occasion a maximum variation was found of 6.9 per cent. between the plain and carburetted arrangements, and an average difference of 0·37 candles, or 4·1 per cent. More concordant results were obtained on subsequent occasions, but variations were sometimes observed, as shown in the tables.

The second set of observations (Table XV.) was conducted to ascertain the differences obtainable when uncarburetted gases of various illuminating power are burnt in the Methven arrangement. From the results obtained I find that the luminosity of the comparison flame may be apparently increased or decreased by even slight variations in the quality of the gas used; on one occasion 14·5 candle gas burnt in the Methven made 16·0 candle gas burnt in the Standard burner appear to be equal to 17·98 candles, while 15·4 candle gas burnt in the Methven gave 0·76 candle higher result than when carburetted gas was used with the smaller slotted screen. These results may be objected to as exceptional, but I venture to think that the possibility of such variations as I have found being obtainable must seriously militate against the adoption of the *plain* gas Methven slot as a standard, however useful it may be as a handy instrument in ordinary works. The arrangement for carburetting the gas is, on the other hand, undoubtedly a very different thing and capable of very reliable work.

The third set, "observations by different operators" (Table XVI.), cannot be considered as very satisfactory. Evidently more experience with the *carburetted* gas is required than would appear necessary.

The generally accepted opinion that the Methven screen may be used after being alight a few minutes, has proved in my hands very misleading. It will be seen, on examination of the tables, that many of the results there recorded are so discrepant that, if taken by themselves, they would seriously call in question the reliability of Mr. Methven's device. I was at a loss to account for them until I had an opportunity of consulting Mr. Methven on the subject. Together we made a series of careful observations which I have put forward in Table XVII. From the results of these it is evident that at least 15 minutes should elapse after lighting the burner before readings are taken, and should the chimney be changed, another five minutes should be allowed for the arrangement to become thoroughly warm again. At first I thought that the fact of a glass chimney being used would account for some of the variations I had noticed, as the portion of the glass in front of the slot would act as a lens. No doubt this is so to a certain extent, but tests made with about 20 different chimneys, some thick and some thin, have demonstrated that no serious error is due to this cause if due care be taken to thoroughly warm the apparatus before using it.

I have put forward the various results which I have obtained, some of which aptly illustrate the dangers to be avoided when using the screen. Unfortunately the time at my disposal has not allowed me to repeat many of the observations as I should otherwise have done. When the carburetted gas is used, great care is required to avoid too large a flame, in which case the readings would be too high.

TABLE XIV.—MR. METHVEN'S SCREEN.

"Plain" *versus* "Carburetted" Gases.

Date.	Methven's Screen and Gas used.	Value ascribed to comparison flame by		Per centage variation from mean.
		Plain Gas.	Carburetted Gas.	
1885.				
January 1	Double slotted screen, with same gas carburetted	..	10·67	− 3·5
,,	,, ,,	..	10·67	− 3·5
,,	,, ,,	..	10·77	− 2·6
,,	Double slotted screen, with 16·0 candle gas carburetted ..	..	=10·81 10·67	− 3·5
,,	,, ,,	..	11·03	− 0·2
,,	,, ,,	..	11·03	− 0·2
,,	Double slotted screen, with 16·0 candle gas, plain	11·42	..	+3·4
,,	,, ,,	11·32	..	+2·5
,,	,, ,,	11·42	..	+3·4
,,	,, ,,	11·02	..	− 0·3
,,	,, ,,	11·08	..	+0·3
,,	,, ,,	11·02	..	− 0·3
,,	,, ,,	11·18 =11·18	..	+1·2
,,	,, ,,	11·18	..	+1·2
,,	,, ,,	11·18	..	+1·2
,,	No. 1, single slotted Screen, with 16·0 c. gas	11·08	..	+0·3
,,	,, ,,	11·08	..	+0·3
,,	,, ,,	11·18	..	+1·2
		Mean 11·05		

TABLE XIV.—MR. METHVEN'S SCREEN—*Continued.*

Date.	Methven's Screen and Gas used.	Value ascribed in comparison flame by		Per centage variation from mean.
		Plain Gas.	Carburetted Gas.	
1885.				
January 8	Double slotted screen, with plain 16·0 c. gas	11·36	..	+2.7
,,	,, ,,	11·37	..	+2·8
,,	,, ,,	11 23 =11·31	..	+1·6
,,	,, ,,	11·21	..	+1·4
,,	,, ,,	11·39	..	+3 6
,,	Same, with "carburetted" gas	..	11·02	−0·4
,,	,, ,,	..	10·87	−1·8
,,	,, ,,	..	10·85 =10·93	−1·9
,,	,, ,,	..	10·95	−1·0
,,	,, ,,	..	10·86	−1·9
,,	,, ,,	..	11·03	−0·3
,,	Same, with "plain" gas ..	10·92	..	−1·3
,,	,, ,,	11·04 =10·95	..	−0·2
,,	,, ,,	10·92	..	−1·3
,,	,, ,,	10·94	..	−1·1
		Mean 11·06		
January 9	Double slotted screen, 16.0 candle plain gas	13·13 13·20	..	+4·0
,,	,, ,,	13·26	..	+5·0
,,	Same, with gas carburetted ..	..	12·54	−0·7
,,	,, ,,	..	12·49 12·48	−1·2
,,	,, ,,	..	12·41	−0·2
,,	Same, with gas plain ..	12·41	..	−0·2
,,	No. 2, single slotted screen, with same gas, plain	12·19 12 30	..	−3·5
		Mean 12·63		
January 10	Double slotted screen, with 16·0 candle gas, plain	13·59	..	+0·5
,,	,, ,,	13·37 13·54	..	−1·2
,,	,, ,,	13·56	..	+0·3
,,	,, ,,	13·62	..	+0·8
,,	Same, with gas carburetted ..	..	13·07	−3·6
,,	,, ,,	..	13·51	−0·0
,,	,, ,,	..	13·42 13·34	−0·8
,,	,, ,,	..	13·36	−1·2
,,	No. 1 screen, with gas plain..	13·66	..	+1·1
,,	,, ,,	13·74 13·67	..	+1·8
,,	,, ,,	13 60	..	+0·6
,,	No. 2 screen, with gas plain..	13·77	..	+1·9
,,	,, ,,	13·52 13·60	..	0·0
,,	,, ,,	13·52	..	0·0
		Mean 13·52		
January 19	No. 1 screen, with 16·3 candle gas, plain	13·26	..	+0·5
,,	Double slotted screen, with same 13·26 c. gas carburetted ..	..	13·14	−0·5
		Average 13·20		
January 23	Double slotted screen, with main gas, plain	16·34	..	+1·2
,,	Do. gas carburetted	..	16·44	−1·2
		Mean 16·64		
,,	Double slotted screen, with same enriched 16·0 c. gas, plain	19·26	..	+2·0
		19·52	..	+3·4
,,	Do. carburetted	..	18·24	−3·4
		..	18·52	−1·1
		Mean 18·88		

37 per cent. within 1 per cent. of the mean.

Table XV.—MR. METHVEN'S SCREEN.

Poor and Rich Gas in Screened Burner.

Date.	Gas burnt in Methven Screen.	Value ascribed to comparison flame.	If 16·0 c. and carburetted gas tests are correct, then other gases give following results.
			Candles. Candle.
1884. December 11	16·0 candle	15·00	15·0 gives + 0 20
,, ,,	Same as comparison flame ..	15·20	
,, ,,	16·0 candle	13·96	14 0 ,, + 0·04
,, ,,	Same as comparison flame ..	14·00	
,, 12	16·5 candle	14·50	14·5 ,, + 0·60
,, ,,	Same as comparison flame ..	15·10	
,, ,,	16·5 candle	14·40	14 4 ,, + 0·70
,, ,,	Same as comparison flame ..	15·10	
,, ,,	16 5 candle	16·10	14·5 ,, + 1 88
,, 18	14·5 ,, ...	17·98	
,, ,,	16·0 candle	11·74	11·74 ,, + 2 04
,, ,,	Same as comparison flame ..	13·70	
,, ,,	16·0 candle	11·60	11·60 ,, + 2·60
,, ,,	Same as comparison flame ..	14·20	
,, 22	16·0 candle	22·00	12·00 ,, + 5·00
,, ,,	12·0 ,, ...	27·00	
,, 19	16·3 candle	13·26	13.26 ,, + 0·90
,, ,,	Same as comparison flame ..	14·16	
November 26	16·0 candle	18·50	10·0 ,, +12·80
,, ,,	10·0 ,, ...	31·30	
,, 27	16 candle	17·00	10·0 ,, + 5·00
,, ,,	10 ,, ...	22·00	
1885. January 26	Carburetted gas..	15·44	15·44 ,, + 0·76
,, ,,	Same as comparison flame ..	16·20	
,, ,,	Carburetted gas..	14·74	14·74 ,, + 0·86
,, ,,	Same as comparison flame ..	15·60	

Table XVI.—METHVEN'S SCREEN.

Observations by various Operators.

Date.	Description of Gas burned in Methven burner.	Value ascribed to Comparison flame.	Percentage variation from mean.	Observers.
1885.		16 60	−6·7	D.
Feb. 4	Same as comparison flame, plain	Chimney turned half-round.		
,,	,,	16·80	−5·6	,,
		Chimney turned half-round.		
,,	,,	16·60	−6·7	,,
		Chimney moved half-round.		
,,	,,	16·80	−5·6	,,
,,	Carburetted gas	18·00	+1·2	,,
		Chimney moved.		
,,	,,	18·00	+1·2	,,
,,	,,	18·00	+1·2	B.
		Chimney moved.		
,,	,,	18·40	+3·4	,,
		Chimney moved.		
,,	,,	18·66	+4·9	,,
		Chimney moved.		
,,	,,	18·42	+3·6	,,
,,	,,	18·50	+4·0	,,
		New chimney.		
,,	,,	18.86	+6·0	,,
		Chimney moved.		
,,	,,	18·50	+4·0	,,
,,	,,	18·44	+3·7	,,
,,	Same gas, plain	17·50	−1·6	,,
,,	,,	17·60	−1·0	,,
,,	,,	17·64	−0·8	,,
,,	,, carburetted.. ..	17·50	−1·6	,,
		Chimney moved.		
,,	,, ,,	18·80	+1·2	,,
		Flame re-adjusted.		
,,	,, ,,	18·20	+2·3	,,
,,	Same gas, plain	16·77	−5·8	A.
,,	,, ,, ...	16·72	−6·0	,,
,,	,, carburetted	18·04	+1·4	,,
,,	,, ,, ...	17·60	−1·0	,,
		Mean 17·79		

12·5 per cent. of the tests, within 1 per cent. of the mean.

TABLE XVII.—MR. METHVEN'S SCREEN.

Tests made alternately by Messrs. Dibdin and Methven.

Date.	Comparison flame.	Gas burnt in Methven.	Chimney used.	Value ascribed to comparison flame.
1885. Feb. 19	Stored gas in 100-ft. Holder	16·5 candle gas plain	No. 1 as set	13·0
,,	,,	,,	,, ,, ...	12·9
,,	,,	,,	,, turned half round	13·2
,,	,,	,,	,, ,, ..	12·7
,,	,,	,,	,, ,, ..	12·8
,,	,,	,,	,, ,, ..	12·7
,,	,,	,,	,, again moved ..	12·7
,,	,,	,,	,, ,, ..	12·5
,,	,,	,,	,, ,, ..	12·3
,,	,,	,,	,, ,, ..	12·3
,,	,,	,,	No. 2 as set	12·7
,,	,,	,,	,, ,, ...	12·7
,,	,,	,,	,, turned ¼ round ..	12·7
,,	,,	,,	,, ,, ..	12·5
,,	,,	,,	,, again moved ..	12·4
,,	,,	,,	,, ,, ..	12·3
,,	,,	,,	,, ,, ..	12·2
,,	,,	,,	,, ,, ..	12·2
,,	,,	,,	No. 3 as set	12·4
,,	,,	,,	,, ,, ...	12·3
,,	,,	,,	,, turned ¼ round ..	12·2
,,	,,	,,	,, ,, ..	12·2
,,	,,	,,	,, again moved ..	12·1
,,	,,	,,	,, ,, ..	12·2
,,	,,	,,	,, ,, ..	12·2
,,	,,	,,	,, ,, ..	12·2
,,	,,	,,	,, flame turned up ..	12·2
,,	,,	,,	,, ,, ..	12·1
,,	,,	,,	No. 4 as set	12·3
,,	,,	,,	,, ,, ...	12·3
,,	,,	,,	,, turned ¼ round ..	12·2
,,	,,	,,	,, ,, ..	12·2
,,	,,	,,	,, again moved ..	12·2
,,	,,	,,	,, ,, ..	12·1
,,	,,	,,	No. 5 as set.	Readings commenced at *once*.
,,	,,	,,	,, ,, ...	11·4
,,	,,	,,	,, ,, ...	12·0
,,	,,	,,	,, ,, ...	11·9
,,	,,	,,	,, ,, ...	11·8
,,	,,	,,	,, ,, ...	11·6
,,	,,	,,	,, ,, ...	12·0
,,	,,	,,	,, ,, ...	11·9
,,	,,	,,	,, ,, ...	12·2
,,	,,	,,	,, ,, ...	12·2
,,	,,	,,	,, ,, ...	12·3
,,	,,	,,	,, ,, ...	12·0
,,	,,	,,	,, ,, ...	12·2
,,	,,	,,	,, ,, ...	12·2
,,	,,	16·5 candle gas carburetted.	,, ,, ...	12·4
,,	,,	,,	,, ,, ...	12·4
,,	,,	,,	,, ,, ...	12·4
,,	,,	12·2 candle gas carburetted.	,, ,, ...	12·3
,,	,,	,,	,, ,, ...	12·4
,,	,,	,,	,, ,, ...	12·5

MR. SUGG'S 10-CANDLE TEST.

This arrangement for obtaining a substitute for candles as the standard of light has one great advantage in that it approximates more nearly to the power of the light under examination. It consists of a small argand burner specially constructed to give a steady flame of three inches in height. The light from the upper portion of this flame is cut off by means of a screen. The inventor contends that any increase in the power of the gas used tends to raise the body of white flame higher, and so increase the volume of blue flame, which compensates for the increase in power of the light-giving portion; so that whatever quality of gas may be used, the total luminosity of that portion of the flame emitting light beneath the screen is nearly constant. That this is so to a great extent is certain, but with poor gas the rule does not hold good, and correction must be made for the decrease in the volume of light which is known to be emitted from the burner under the particular conditions. This system has great advantages. In the first place the burner is in itself a good approximate photometer, as it is arranged to work precisely on the principle of the illuminating power meter of the same inventor, so that observations taken of the consumption of gas required to yield a flame of the proper height give very good indications of the illuminating power of the gas used. Secondly, I find that there is no difference in the readings of the photometer screen when the flame of the 10-candle test is raised three-quarters of an inch above the regulated height, or lowered half an inch beneath. (Table XVIII.) Such variations as these, however, could hardly occur in practice. I also find (Table XIX.) that there is little difference in the results when either 17·0 candle gas, or the same, or a poorer quality of gas carburetted with the vapour of pentane is used. For the purpose of a standard of reference I consider that the quality of the gas used should be as nearly as possible constant, and as the system of carburation is most easily and satisfactorily applied, I would suggest that this form of gaseous fuel should be used, in which case I think that the 10-candle test devised by Mr. Sugg is well worthy of a place amongst the proposed standards of light.

TABLE XVIII.—MR. SUGG'S 10-CANDLE LAMP.

Date.	Comparison flame.	Height of flame in "10-candle test burner.	Value ascribed to comparison flame.	Gas burnt in "test" burner.
1885.				
Feb. 20	Gas stored in 100 ft. holder	At regulated mark ..	14·4	Service.
,,	5 ft. per hour ..	1¼ in above ,, ..	15·0	,,
,,	,, ,,	⅝ in. ,, ,, ..	14·4	,,
,,	,, ,,	¾ in ,, ,, ..	14·4	,,
,,	,, ,,	1 in. ,, ,, ..	14·3	,,
,,	,, ,,	1¼ in. ,, ,, ..	14·9	Stored gas exhausted.
,,	Service 5 ft. per hour	At regulated mark ..	16·87	Service.
,,	,, ,,	⅜ in. below ,, ..	16·80	,,
,,	,, ,,	⅝ in. ,, ,, ..	17·00	,,
,,	,, ,,	¾ in. ,, ,, ..	18·00	,,
,,	,, ,,	At regulated mark ..	16·94	,,
,,	,, ,,	¾ in. above ,, ..	16·96	,,
,,	,, ,,	At regulated mark ..	16·83	,,
			20·04	100 ft. holder gas.
Feb. 21	,, ,,	¾ in. below regulated mark	17·75	Carburetted service.
,,	,, ,,	½ in. ,, ,, ..	17·50	,,
,,	,, ,,	¼ in. ,, ,, ..	17·70	,,
,,	,, ,,	At regulated mark ..	17·40	,,
,,	,, ,,	¼ in. above ,, ..	17·70	,,
,,	,, ,,	At regulated mark ..	17·70	,,
,,	,, ,,	¼ in. above ,, ..	17·45	,,
,,	,, ,,	½ in. ,, ,, ..	17·80	,,
,,	,, ,,	¾ in. ,, ,, ..	18·20	,,
,,	,, ,,	At regulated mark ..	17·80	,,
,,	,, ,,	,, ,, ..	17·50	Uncarburetted.
,,	,, ,,	,, ,, ..	21·25	100 ft. holder gas.

TABLE XIX.—MR. SUGG'S 10-CANDLE TEST.

Date.	Comparison flame.	Gas burnt in 10-candle test.	Value ascribed to comparison flame.
1885.			
Feb. 23	Gas stored in 100 ft. holder, 5 ft. per hour ..	16·7 candle gas plain ..	13·7
,,	,,	,, ,,	13·7
,,	,,	,, ,,	13·8
,,	,,	13·8 ,, ,,	16·8
,,	,,	,, ,,	16·7
,,	,,	Harcourt's pentane air-gas, 2·55 ft. per hour	25·0
,,	,,	Do. carburetted	15·1
,,	,,	16·7 candle gas carburetted ..	14·2
,,	,,	,, ,, plain ..	14·4
,,	,,	,, ,, carburetted ..	14·2
,,	,,	,, ,, plain ..	14·15
,,	,,	,, ,, carburetted ..	14·12
,,	,,	,, ,, plain ..	14·2
,,	,,	14·2 ,, carburetted ..	14·23
,,	,,	,, ,, ,,	14·15
,,	,,	,, ,, plain ..	16·17

COMPARISON TESTS.

The only satisfactory method of accurately comparing the power of various standards of light would be by means of a three or four way photometer, *i.e.*, three or four photometer bars arranged radially so that one central light should be simultaneously tested by the competing standards, one at the opposing end of each bar. I regret that the space and apparatus at my disposal have precluded the adoption of such an arrangement. I have, therefore, availed myself of the next best alternative, viz.: the testing from time to time, of a flame, as nearly constant for the time being as it is possible to obtain, by means of the various proposed standards in rapid succession. The necessarily intermittent character of the work has rendered these tests of a more variable nature than I should have preferred; but such as they are, they have been made with care, and, it is believed, approximate closely to the truth.

On two occasions the comparisons were made on different photometers. On the 20th January, on two instruments, viz.: the "Bar" and "Portable" photometers. On the 21st January three photometers were used; the "Bar," "Portable" and "Radial." Candles were tested on the Portable, Methven's screen on the Radial, and the Keates' lamp and Harcourt's pentane on the Bar.

Unfortunately, in consequence of the cold weather prevailing, the gas, which was drawn from the service, and had to travel through a long length of exposed pipe, fell considerably in value during the period of testing, so that the tests must be taken as they stand, the value usually attached to mean results being neutralised. I was obliged to abandon the use of the stored gas in the 100-feet holder, as I found that the standard burners in the three photometers, although giving identical results with ordinary 16-candle gas, were useless for the purpose of comparison

when a gas of 12-candle power was used, which was the value of the gas after storage during cold weather in the 100-feet holder. On nearly all the other occasions when comparison tests were made the stored gas burnt in one photometer was used.

From a careful inspection of the accompanying table of "Comparison Tests," it will be seen that there is a very close accordance between the Pentane, Keates' lamp, and the Methven, whilst all three agree in the main with candles. The Methven screen was, with the exception of candles, the most variable.

I may now revert to the remarks of Messrs. Heisch and Hartley, as to the quantity of light afforded by candles being greater at the present time than formerly. I have put forward the results of the tests made for the purpose of standardising the Keates' lamp in the early part of 1879. Mr. Harcourt's pentane was standardised about the same time, or a little earlier. I find that these standards, as well as the Methven, closely agree with a large number of candle tests made shortly before or after they were used. I also find that the Carcel Lamp, as compared with the "Pentane" and the "Keates' Lamp," is equal to 9·4 candles, while a number of tests made by Mr. Sugg in 1870, shewed its value to be 9·6 candles. I am consequently driven to the conclusion that the average quantity of light per unit of sperm consumed, emitted by good candles, is practically the same as when the lamp and the pentane were standardised, viz., 1878 and 1879, and as when Mr. Sugg tested the "Carcel" in 1870. So far from candles giving more light, the tendency is to give less light, and so apparently enhance the value of the gas.

As this is a matter of great moment, I propose, with the sanction of your Committee, to continue, as time will permit, the course of experiments I have commenced, and to report the results at a later period.

As other pressing matters of importance require my undivided attention, I have thought it best to submit the results already obtained.

TABLE XX.—COMPARISON TESTS.

Date.	Comparison flame.	Value ascribed to comparison flame by—				
		Candles.	Keates lamp.	Pentane.	Methven.	
					Plain.	Carburetted.
1884						
Dec. 11	Stored gas, 5ft. per hour in standard burner	14·7	14·0	13·9	15·0	..
,,	,, ,,	15·4	14·1	14·1	15·2	..
,,	,, ,,	14·6	13·9	13·9	14·0	..
,,	,, ,,	..	..	..	14·0	..
	Mean	14·9	14·0	14·0	14·5	..
Dec. 12	Stored gas, 5ft. per hour in standard burner	14·7	14·6	14·6	15·6	..
,,	,, ,,	15·2	14·7	14·6	15·5	..
,,	,, ,,	15·4	14·8	14·6	15·8	..
,,	,, ,,	..	..	14·4	..	..
,,	,, ,,	..	..	14·4	..	..
,,	,, ,,	..	..	14·4	..	..
	Mean	15·1	14·7	14·5	15·6	..

TABLE XX.—COMPARISON TESTS—*Continued.*

Date.	Comparison flame.	Value ascribed to comparison flame by—				
		Candles.	Keates' lamp.	Pentane.	Methven.	
					Plain.	Carburetted.
1884.						
Dec. 16	Stored gas, 5ft. per hour in standard burner	..	14·9	14·4	14·7	..
,,	,, ,,	..	14·6	14·2	15·3	..
,,	,, ,,	..	14·2	14·5	14·7	..
,,	,, ,,	..	..	14·7	15·4	..
,,	,, ,,	..	..	14·6	..	..
,,	,, ,,	.	..	14·4	..	..
	Mean	..	14·6	14·5	15·0	..
Dec. 16	Service	16·7	..	16·7	..	..
Dec. 18	Service	..	16·8	16·8	..	..
,,	Stored gas, 5ft. per hour in standard burner . ..	..	11·7	11·6	11·7	..
,,	,, ,,		11·8	11·6	11·6	..
	Mean	..	11·75	11·6	11·65	..
Dec. 20	Stored gas arranged for small flame	..	4·8	4·8	5·0	..
,, 22	Service, 6·5 ft. in argand burner	..	23·0	22·0	22·0	..
1885						
Jan. 1	Stored gas, 5 ft. in standard burner	..	10·9	11·4	11·4	10·8
,,	,, ,,	..	10·9		11·1	10·9
,,	,, ,,	..	11·2	..	11·2	..
				..	11·1	..
	Mean ..	..	11·0	11·4	11·2	10·85
Jan. 8	Stored gas, 5 ft. per hour in standard burner	..	10·9	11·2	10·9	11·0
,,	,, ,,	..	10·6	..	11·0	10 9
,,	,, ,,	..	..	..	10·9	10·9
,,	,, ,,	..	..	..	10·9	11·0
,,	,, ,,	..	..	..	..	10·9
,,	,, ,,	..	..	..	..	11·0
	Mean ..	..	10·75	11·2	10.9	10·95
Jan. 12	Stored gas, 5 ft. per hour in standard burner	12·5	12·5	12·2	12·5	..
,,	,, ,,	12·7	12·2	12·2	12·3	..
,,	,, ,,		12·4	12·1	12·8	..
				12·2		
	Mean ..	12·6	12·4	12·2	12·5	..
Jan. 13	Stored gas, 5 ft. per hour in standard burner	..	13·3	12·8	13·4	..
,,	,, ,,	..	13·3	12 8	13·3	..
,,	,, ,,	..	13·5	12·8	13 1	..
,,	,, ,,	..	13·2	12·8	13·2	..
,,	,, ,,	..	13·5	..		
,,	,, ,,	..	13·3	..		
	Mean ..	..	13·3	12·8	13·25	..
Jan. 17	Service, 5ft. per hour in standard burner	16·0	16·1	..	16·4	..
,,	,, ,,	..	16·0	..	..	..
,,	,, ,,	..	16·0	..	..	..
	Mean ..	16·0	16·0	..	16·4	..

TABLE XX.—COMPARISON TESTS—*Continued.*

Date.	Comparison flame.	Value ascribed to comparison flame by—				
		Candles.	Keates lamp.	Pentane.	Methven.	
					Plain.	Carburetted.
1885.						
p.m.	Simultaneous tests on two photometers.					
Jan. 20 7.15	Service, 5ft per hour in standard burner	16·7	..	16·9	16·9	..
,, 7.30	,, ,,	16·9	..	17·0	16·8	..
,, 7.40	,, ,,	16·9	..	17·0	16·7	..
,, 8.10	,, ,,	16·5	16·5	..	17·0	..
,, 8·40	,, ,,	16·4	16·5	..	17·0	..
,, 8.50	,, ,,	15·9	16·0	15·6	15·9	..
,, 9.15	,, ,,	14·6	15·9	15·0	15·8	..
,, 9.30	,, ,,	..	..	14·8	14·8	..

The rapid depreciation in the quality of the gas used neutralises the value usually attached to mean results. This remark also applies to the following series:—

1885. p.m.						
Jan. 20 5.25	Service 5ft. per hour in standard burner	..	..	15·4	..	..
,, 6.30	,, ,,	..	..	15·4	..	..
,, 6.45	,, ,,	15.9	..	15·6	..	..
,, 7.5	,, ,,	16·2	..	16·1	..	..
,, 7.20	,, ,,	16·1	..	..	..	..
,, 7.50	,, ,,	..	15·5	..	16·6	..
,, 7.55	,, ,,	16·3	..	..	..	..
,, 8.10	,, ,,	..	15·7	..	16·1	..
,, 8·20	,, ,,	..	..	..	15·3	..
,, 8.40	,, ,,	15·7	..	..	15·2	..
,, 8.45	,, ,,	..	..	15·7	16·5	..
,, 9.0	,, ,,	15·6	..	15·0	15·4	..
,, 9.10	,, ,,	..	..	..	15·1	..
,, 9.30	,, ,,	15·6	..	..	..	..
,, 9.40	,, ,,	..	15·1	..	..	..

The above tests were made, as nearly as possible simultaneously, on three photometers by three observers. The candle tests were made on the "Portable" photometer; the lamp and Pentane tests on an ordinary "Bar" photometer; and the Methven tests on the "Radial" photometer. The meters and burners had previously been carefully compared and found to give identical results.

1885.						
Jan. 23	Enriched gas	..	..	18·8	..	18·2
,, ,,	,, ,, ...	..	..	18·6	..	18·5
	Mean	..	..	18·7	..	18·4
						Carcel.
Feb. 10	Gas stored in 100 ft. holder, 5.5 ft. per hour ..	17·14	17·13	..	..	1·776
,, ,,		18·13	17 18	..	..	1·775
,, ,,	,, ,, ,,	..	..	..	..	1·756
,, ,,	,, ,, ,,	..	..	..	..	1·846
	Mean	17·63	17·15	..	..	1·783
						Methven.
Feb. 11	Gas stored in 100 ft. holder, 5 ft. per hour ..	16·46	16·60	16·35	15·70	16·20
,, ,,		16·56	16·36	16·55	15 64	16·20
,, ,,	,, ,, ,,	..	16·34	..	15·80	..
,, ,,	,, ,, ,,	..	..	..	16 04	..
,, ,,	,, ,, ,,	..	..	..	16·20	..
	Mean	16·51	16·43	16·45	15·87	16 20
Feb. 17	100 ft. holder gas	16·46	15·98	15·98	..	..
,, ,,	,, ,, ,, ...	15·98	..	15·78	..	..
,, ,,	,, ,, ,, ...	15·78	..	16·00	..	..
	Mean	16·07	15·98	15·92	..	..

RECOMMENDATION.

Looking to the results which I have obtained, and the great number of published tests by various experienced observers, I am of opinion that the public is now in possession of four reliable substitutes for candles as standards of light. These may, however, be reduced in principle to *two*, as in three of them the combustible employed is identical, viz., Pentane. In the original form the Pentane was used by Mr. Harcourt as an air-gas, the flame adopted being equal to one candle; in the second form Mr. Methven burns a large flame charged with this substance, but takes only a small portion of it, which is equal to *two* candles; Mr. Sugg would take, in the form which I have suggested (as ordinary coal gas is in my opinion inadmissible as a standard combustible), a smaller flame than Mr. Methven, but would utilise the greater portion of it, and so obtain a light equal to 10 candles. The other standard, the Keates' lamp, is entirely different in every respect, and yields a light equal to 16 candles. Which of these should be finally adopted is, in my opinion, of litle practical moment. Individually, I would prefer that which approximates most nearly to the power of the light under observation, as the readings are sharper and there is less liability to error from air currents disturbing the standard flame. With the Keate's lamp observations may be made under circumstances which would be prohibitory to the Pentane, Methven's screen, or the 10-candle test; in addition to which, the portability of the lamp is of no mean consequence. Mr. Harcourt has endeavoured to meet this contingency by means of the Pentane lamp, but from the limited experience I have had with it, I venture to think that considerable modifications are required before it could be admitted as a legal standard. The Methven screen has great advantages, but undoubtedly requires more care in handling than at first sight appears necessary.

I recommend that before either of these proposed substitutes for candles be finally adopted as the standard of light, that a systematic series of tests be made on a four-way photometer, as I have indicated, for the purpose of determining, under conditions beyond all question, which, in practical work, gives the most uniform results and the closest approximation to the legal standard at present in use in this country.

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